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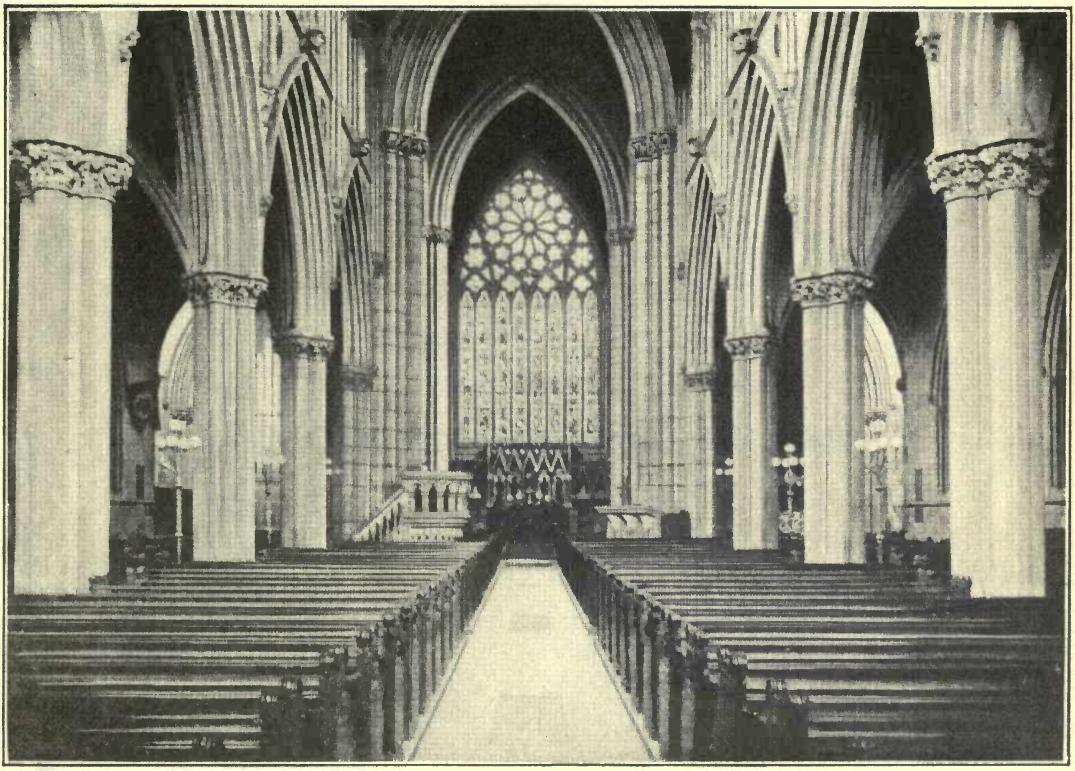
THE
MODERN
BRITISH ORGAN

NOEL A. BONAVIA-HUNT, M.A.



DONCASTER PARISH CHURCH (THE NAVE)

THE
MODERN BRITISH ORGAN

PUBLISHER'S FOREWORD

In presenting THE MODERN BRITISH ORGAN *to the world of organ lovers, it is felt that the technical knowledge and experiences of the author should be placed on record.*

At the same time it must be emphasized that such complex matters as tonal structure, and tone qualities, have their host in each individual.

No treatise could be compiled completely by any one technologist to cover such a wide subject as an organ.

Search and research there must inevitably be, and we do not claim that this work is devoid of errors.

Omissions, too, there may be also.

While we cannot accept responsibility for expressions of opinion, or inaccuracies, we earnestly request readers who feel such exist, to present their viewpoint.

By this, they will assist in presenting to others a work that will prove invaluable.

NEW & REVISED EDITION

THE
MODERN BRITISH ORGAN

A theoretical and practical Treatise
on the Tone and Mechanism of
the King of Instruments

by

NOEL A. BONAVIA-HUNT, M.A.
PEMBROKE COLLEGE, OXFORD

"*Multisonis quatiant haec organa vocibus aures,*
Quae tibi miranda struxerit arte faber."

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PREFACE

In presenting this book to the Organ Lover I am anxious to dispel any possible misconception as to its scope and aim, and accordingly would emphasise the fact that it has not been written for the professional organ builder, nor does it claim to supply information on every conceivable subject relating to the science, art and craft of organ construction. It is to a very large extent a personal contribution to the fund of knowledge which is the common property of the makers and lovers of the King of Instruments. I owe so much to the Organ as a never-ending source of joy and a never-failing distraction from the cares of life that I feel I want to discharge some of that debt by recording my experiences and helping others who are seeking for information to appreciate all that is best and highest in the art of organ building. I am aware that I cannot teach the organ builder very much: if he does me the honour of reading these pages my hope is that he will find them interesting, for I have tried to make the script readable, and in pursuit of this object have from time to time introduced an anecdote or some reference to a friend or well-known organist or builder whose views have in my opinion been worth recording. Without such interpolations a book of this kind can be very dull and demand undue concentration on the reader's part. Those who have made personal contact with me either in the flesh or through the medium of my previous books will expect to find in this one a goodly proportion of printed matter devoted to the tonal aspect of the King of Instruments, and their anticipations will be correct. I have certainly had something to say on this, to me, all-important subject; but I would point out that, although I can now look back upon a fairly long vista of years devoted to the study of my favourite musical instrument, my personal views on organ tone have not become crystallised into a one-track attitude which can see nothing good or desirable in the ideals or conceptions of those whose tastes differ—perhaps even fundamentally—from my own. This is a snare from which advancing years has mercifully released me. I very nearly succumbed to the temptation, but the "polythematic idea" saved me. From henceforth I can scan the courts of the "temple of tone" with a benignant eye for all that is aesthetically acceptable on the grand scale of nature's aesthetic law. I listen to the tones of an organ, and as I listen my mind weaves tone-pictures and draws figures on an invisible scroll: to these I apply judgment on the lines laid down in my chapter on "Tonal Architecture"—a judgment which to be fair must at least try to be generous.

I have borne in mind those amateur constructors from whom so often I have received letters soliciting my advice. But I must warn them that nothing takes the place of practical experience, and that there are and must be many details of construction and design which no book can give them. Moreover, there is a limit in these days to the number of pages permissible to an author engaged in writing a treatise on a specialised subject such as organ building, and, thanks to the generosity of the publishers, I have been allowed a larger amount of space than I could reasonably have expected. I hope, however, that there are no serious omissions in any part of the book, and that such data as I have given will prove adequate for all ordinary needs. It has obviously been impossible for me to include the names of every worthy builder, and I would most emphatically state that the omission of a builder's name does not imply that he has made no worth-while contribution to the art of organ building:

on the contrary, there are quite a number of firms, large and small, who have striven most earnestly and energetically to advance the art and have produced results worthy of the highest commendation. I entertain the deepest respect for the British organ builder and am only too vividly aware of the multitudinous difficulties that are so frequently placed in his way. Nevertheless, it is a commonplace truism that certain men stand out pre-eminently in the history of organ development, and it is quite impossible to do justice to any survey of that development if their names are omitted. And here I should like to add that this book does not include in its schedule of contents the historical aspect of the King of Instruments: the story of the Organ has been written by others fully capable of telling it, and I have only referred to the past in connection with this or that component in the structure of the Organ when I felt such a reference was essential to the full understanding of its mechanism or character. If the reader is able to point to an exception to this rule, I will not apologise: that exception only proves the rule, and exceptions are sometimes an acceptable condiment lending flavour to the drabness of a technical exposition.

I have received many kindnesses from organ builders and organ lovers in in the compilation of this book which I desire to acknowledge. To Mr. J. Clarke, of Worcester, I owe a deep debt of gratitude for having prepared a large number of diagrams and plates from my own rough sketches. My best thanks are due to Mr. Henry Willis and Mr. A. Thompson-Allen for the drawings of the "Infinite-speed-and-gradation" Swell Pedal action and the adjustable action associated with their illustrious firm. To Mr. C. Horace Clarke, of Snaresbrook, for eight drawings of various mechanical devices incorporated in his house organ, and to Mr. H. W. Homer, for drawings of electric key and stop action and of his patent direct-electric chest, I am extremely grateful. Mr. John H. Compton kindly supplied me with the specifications of his firm's fine instrument in the Wolverhampton Civic Hall. From America I have been honoured by the most friendly letters, giving me such constructional data as I asked for, from Mr. G. Donald Harrison of the Aeolian-Skinner Organ Company, and from Mr. Ernest M. Skinner, whose name is inseparably associated with the pitman chest and many other inventions both tonal and mechanical. There are many organ builders in the United States who have done and are doing noble work on behalf of the King of Instruments, and though I have not been able to devote the space I should have liked to a description and acknowledgment of their contributions to the advancement of the art, I would have them realise that I am fully aware of the high standard of their work and the loftiness of their ideals. My one regret is that I have had no opportunity of a personal acquaintance of their organs; but if this book falls into their hands I hope that they, as well as their brother craftsmen over here, will derive some enjoyment from these pages. Finally, I would gratefully acknowledge the kindness of Messrs. Harrison and Harrison, Messrs. J. W. Walker and Sons, Mr. Huskisson Stubington, and Mr. Gilbert Benham in permitting me to reproduce the photographs of consoles which appear in this book. To the kindness of the Vicar of Doncaster I owe the frontispiece, and the photograph of myself which appears in the chapter on Voicing is due to my friend Mr. H. A. Frampton, who, despite my warnings that I was a difficult subject for the camera to handle, undertook the risk with a cheerfulness and enterprise that triumphed over all obstacles.

NOEL A. BONAVIA-HUNT,

Stagsden, Bedford.

INTRODUCTION

THE musical instrument commonly known as the Organ is a combination of engineering and art; it represents the fruit of centuries of human endeavour and patience. The Organ is essentially the product of Man, who has unconsciously copied his own bodily mechanism and followed the track of his own amazing evolution from the solitary living cell to the highly complex organism which he calls his physical body. If we examine with an expert eye the design and structure of the modern Organ from its console to its pipes we shall at once recognise the resemblance which its mechanism presents to that of the human brain and its associated nervous system. The organ builder and the anthropologist, on comparing notes, would be surprised at the parallelism that their respective subjects offer and would discover that man has instinctively evolved the Organ after his own image. Indeed, it is this fact more than any other that has impelled him to call his greatest mechanical product the "King of Instruments," since no other instrument of music can vie with it for complexity of design and structure. It is difficult to realise that the magnificent examples of organ construction and tonal effectiveness that grace our cathedrals should have been evolved from the simple Pan-pipe—the "organ" of the Bible—or that there was a time in its history when the most complex and exalted representative of the Organ was the "mouth-organ." Have we not every justification in comparing our present noble instrument in its slow and laborious development from so humble a beginning to that of the human body itself? The introduction of electricity as the motive force, enabling the player to make personal contact with the pipes, affords but a further reason for instituting our comparison, since the nerves of the human body are likewise energised by similar, if minuter, electric charges. I go a step further still in presenting my simile; for if it is argued that the Organ is dumb without the organist, I insist that the human body is equally futile without the personality that uses it. Both the musical and the human instruments are organs that have to be played by persons. My brain is an amazingly complex telephone exchange which *I* use for my own purpose, and the modern electric console of the Organ is a very similar piece of mechanism which the player uses for his own purpose. The two situations are closely parallel, more so than is generally realised.

Now, just as the inner working of the human body demands a very specialised study on the part of the anatomist, so the inner working of the Organ demands an equally specialised study on the part of the organ builder. It can, therefore, hardly be surprising if only a small percentage of the population of a country can be found to take the pains to discover the secrets of the Organ's mechanism. That small percentage is, however, extremely keen on learning as much of its special subject as possible, and this book is an attempt to provide such information as will enable the student to acquire a working knowledge of the construction of the modern Organ. It is not possible in a book of any size (let alone one of this size) to describe the **whole** of organ building even up to its present stage of development, since the building of an organ does not consist only of its paper specification and drawings, nor of the materials employed in its construction. To these must be added the incalculable factors of personal experience and craftsmanship. The amateur student is warned in advance that it is one thing to attain to a mental grasp of the working of a piece of mechanism and quite another thing to be able to put that piece of mechanism together so that it works. Yet further: he may succeed in coaxing it to perform its office as a single, detached piece of mechanism, but unless he is singularly fortunate or a born genius the chances are that that piece of mechanism will refuse to function as an integral part of a collective organism. It is really quite extraordinary how that which appears to look so promising and even fool-proof on paper will mock at the designer as soon as it has been converted into concrete form in terms of metal, wood and leather. These elusive factors immediately present themselves and seem designed to humiliate the experimenter. But thus is wisdom acquired, and patience is ultimately rewarded. The qualifications of a successful organ builder are many and varied. He must have ascertained the optimum sizes of the various parts that make up the whole: he must know how to draw the line between that which is too large and that which is too small: he must be able to arrange the design of every bit of mechanism so that there is a margin of safety providing for all possible contingencies: he must plan with a view to easy access to every minute part in case of accidents: he must select the right and appropriate material for each part: he must combine simplicity of design with efficiency of operation. And these "musts" do not complete the list of his essential qualifications, for above all he must be an artist. A man may be capable of producing a perfect instrument up to the feet of the pipes, and at that point his proficiency and success may come to a sudden and lamentable end! An organ builder is more than a skilled engineer: he is more than an accomplished carpenter: more than an enthusiastic craftsman. He is, or should be, an artist. He need not be a skilled player, but he needs to be a connoisseur of musical tone. We do not ask him to be a musician, but we expect him to possess that aural faculty which enables him to discriminate between good, bad and indifferent tone. For when all is said and done, the organ is designed and put together for the **primary** object of being heard rather than of being seen; and if its sounds are not sweet and agreeable, if its music offends the listener's ear, it has failed in its mission, it "cumbereth the ground."

A man possessing all the qualifications above enumerated is a *rara avis*, one in a generation: usually the qualifications are divided among a group of specialists responsible to a director for their respective contributions. The designer and draughtsman, the setter out, the craftsman, the metal hand, the voicer, the finisher—all combine to produce a work of art. And if they co-operate and understand one another, and if—which is so important—their director is a man of exceptional gifts, the result is a foregone conclusion. A highly skilled and enthusiastic staff of experienced specialists working with one aim and knowing exactly what to do and how to do it is an essential requisite in every organ building factory. But the ideal organ has still to be evolved, and just as in the realm of politics men are learning that they can serve both their own interests and the interests of humanity at large best by acting and behaving with an international outlook, so in the realm of organ building real progress towards the attainment of the ideal instrument can proceed only along the path of co-operative effort and by the fullest recognition of the work and achievements of the builders of all countries.

It will naturally be asked, "What constitutes the ideal organ?" Opinion differs as to the answer, yet surely there must be some definite prescription upon which the great majority of organ lovers would be able to find agreement. Divergence of view is mainly due to the individual temperament of the critic who naturally has his own idea of what an organ should be. But the canons of Art are still valid and provide the criterion by which an instrument purporting to produce beautiful music should be judged. The Organ of to-day is able to boast of a large number of tone-colours which were denied to our forefathers and it would almost appear that the limit of tonal variety has been reached. Yet about this particular aspect of the Organ's evolution I have two observations to make. First, the general impression conveyed to the average musical listener at a recital, and more especially if he is receiving a radio version of it, is a lack of tonal variety: the only incidents that relieve the monotony of the performance being (a) the character of the piece played, (b) the manipulative and technical display of the performer, (c) the changes of intensity, whether gradual or sudden, and (d) the introduction of solo stops. When we compare the Organ with the piano we can only place the last item to the credit of the Organ, the other three being equally at the disposal of the pianist. Secondly, the Organ, if classical tradition is to be preserved, depends for its status in the hierarchy of Art not upon the variety of its tones, but rather upon certain defined characteristics that distinguish it from all other musical instruments. It would be easy to point to instances where stops of unimportant character have ousted from their rightful position in the tonal scheme the basic tones of the Organ. In far too many organs stops of dubious value have been introduced, well voiced and beautifully finished, while the foundation tones which make the Organ what it really is have been improperly designed and treated. The artistry expended on stops that imitate the tones of orchestral instruments might more profitably have been lavished on stops that are essential to the tonal edifice. Fortunately, there is a growing feeling among the organ building fraternity that first things should be put first and that the various "chorus effects" should be perfected before the frills are introduced. Whatever may be our own conception of the ideal, it should embrace all that is best in the achievements of the past and never lose sight of the fundamental character of the King of Instruments.

I have said that the Organ is a combination of engineering and art. The engineer has certainly much to his credit in providing the player with labour-saving controls and gadgets. The tide of mechanical development, especially since the introduction of electrics, has swept on and tended to obscure the claims of the tonal department to at least equal consideration. It is sometimes forgotten that the pipes of an organ are extremely sensitive to the manner in which compressed air is admitted to them, and the engineer who hits upon a new design of soundboard and action which from his point of view completely solves the mechanical problem may be unconsciously ignoring certain aero-dynamic laws upon which the Organ as a musical tone-producer absolutely depends. The soul of the Organ is not to be found in its mechanism which is but a means to the end: it resides in the tone of its pipes. Yet no one would deny to the organist an adequate supply of accessories enabling him to manipulate his instrument and elicit its beauties to the utmost degree possible. If the soul of the Organ is in its pipes, it can nevertheless only be given concrete and material expression by the player at the console, and I should be the last to wish to deprive him of one single necessary control or accessory. Nor would I have him seated at a console so placed that he cannot hear his effects or obtain any idea of what he is doing. But this is not to say that mechanical aids should be introduced without some limit being imposed; for, after all, the organist is very much a human being and is capable of being spoilt. If things are made too easy for him, is he not in danger of becoming slack and of losing some of his forceful personality? I know of cases where this deterioration in artistry has coincided with the provision of increased facilities of control: the man is no longer on his mettle and no longer gives of his best. Perhaps the finest performance of organ music I have ever heard was that which the late lamented Lynnwood Farnam gave on an old Father Willis three-manual instrument built in the seventies with tracker action and only three composition pedals to the swell and great manual stops respectively. He relied on his hands to select the appropriate combinations of stops, and the way in which he succeeded in spite of obstacles in building up his crescendo effects and reducing in smooth gradation from loud to soft by a skilful manipulation of the stop-knobs, to say nothing of the superb artistry of his foot and finger technique, left an indelible impression on me. Sitting as I was in the auditorium, with the visible world entirely shut out and the world of beautiful sounds absorbing my whole being, I felt that, to this performer, the "handicaps" of an obsolete mechanism must be non-existent, that here was an outstanding example of the triumph of mind over matter. I would add—and this is of supreme significance—that I have had the privilege of hearing Lynnwood Farnam on many occasions, and though this was the only instrument of obsolete mechanism on which I heard him perform, not once did he ever excel the performance I have described, certainly not on any organ equipped with the latest controls. I know that he preferred playing on the modern electric organ, which is only natural; but it does not follow that the availability of umpteen accessories is compatible with enhanced tonal results, either from the pipes or the player. I would suggest, therefore, that there should be some "rationing" of mechanical gadgets and that such gadgets as are provided shall be absolutely efficient and reliable.

In the chapters that follow, I shall be guided in my selection of material by the desire to interest my readers, both professional and amateur, and shall show preference for that which is useful and valuable in the construction of an organ. It is but natural that I should have my own views as to what is useful and valuable, and I do not expect the reader invariably to share those views. The true worth of a book of this kind consists in its presentation of facts and measurements, and in this respect I hope I have done my duty as far as in me lies. I have assumed, with perhaps unwarranted optimism, that before many years have elapsed, organ building will see a renascence despite the terrible devastation caused by the second world war. I hope that this renascence will be marked by a new spirit of fraternal co-operation in the industry, that what is worth preserving from the achievements of bygone days will be utilised in any future development that the ingenuity of man may have in store, and that the King of Instruments will retain its exalted position in the kingdom of beautiful sounds.

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CHAPTER I

The Pipes of the Organ

WHEN we listen to an organ being played it is the pipes that produce the musical sounds. Let us therefore begin our study of this wonderful instrument by examining its pipes. Although the principal varieties are illustrated in the Plates and will be described in the text of this and later chapters, it is far better for the student, if possible, to visit an organ factory or to gain access to the interior of an organ so as to obtain a first-hand knowledge of the shapes and construction of organ pipes in general. I was fortunate enough at the early age of sixteen to be able to do the latter, since I was called upon to try my hand at tuning the reeds of the large three-manual organ in the chapel of my school when circumstances rendered such an operation necessary. One may, however, see the pipes without understanding how they speak or why they should produce their particular kind of tone: so I shall try to explain the functions and characteristics of organ pipes in this chapter.

Every pipe in an organ must belong to one of two distinct classes:—

Class I—Those that produce their note through the setting in motion of aerial forces between a slit and an edge.

Class II—Those that produce their note through the setting in motion of a solid vibrator.

The above classification is the only true scientific one. To Class I belong all pipes known to organ builders as "flue pipes." To Class II belong all pipes known to organ builders as (a) reeds and (b) diaphones.

1. Class I—the **flue pipe**—will engage our attention first of all. Various types are shown in Plates I and II; but the reader is asked to look at Figure I, A, showing the various parts. Taking these parts in due order from bottom to top, we observe:—

1. The foot-hole, through which the pressure-wind flows.
2. The foot itself, in which the stream of wind develops its "head," i.e. builds up to maximum pressure and capacity.
3. The languid,* which separates the foot from the body, except for the narrow passage-way or slit shown at the right-hand side of the languid; this slit is called
4. The flue, because the stream of wind has to pass through it, and in so doing finds itself somewhat attenuated in consequence.
5. The mouth, which consists of the lower and upper lips.
6. The body (or "speaking length") in which the sound waves are set in motion up and down in concertina-fashion, thus producing the mature note of the pipe.

Now notice that the pipe will not sound at all if either (a) the foot-hole is closed (b) the flue is closed (c) the flue is too wide (d) the languid is tilted up

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* Variously spelt "languid," "languard," "languet" and "language."

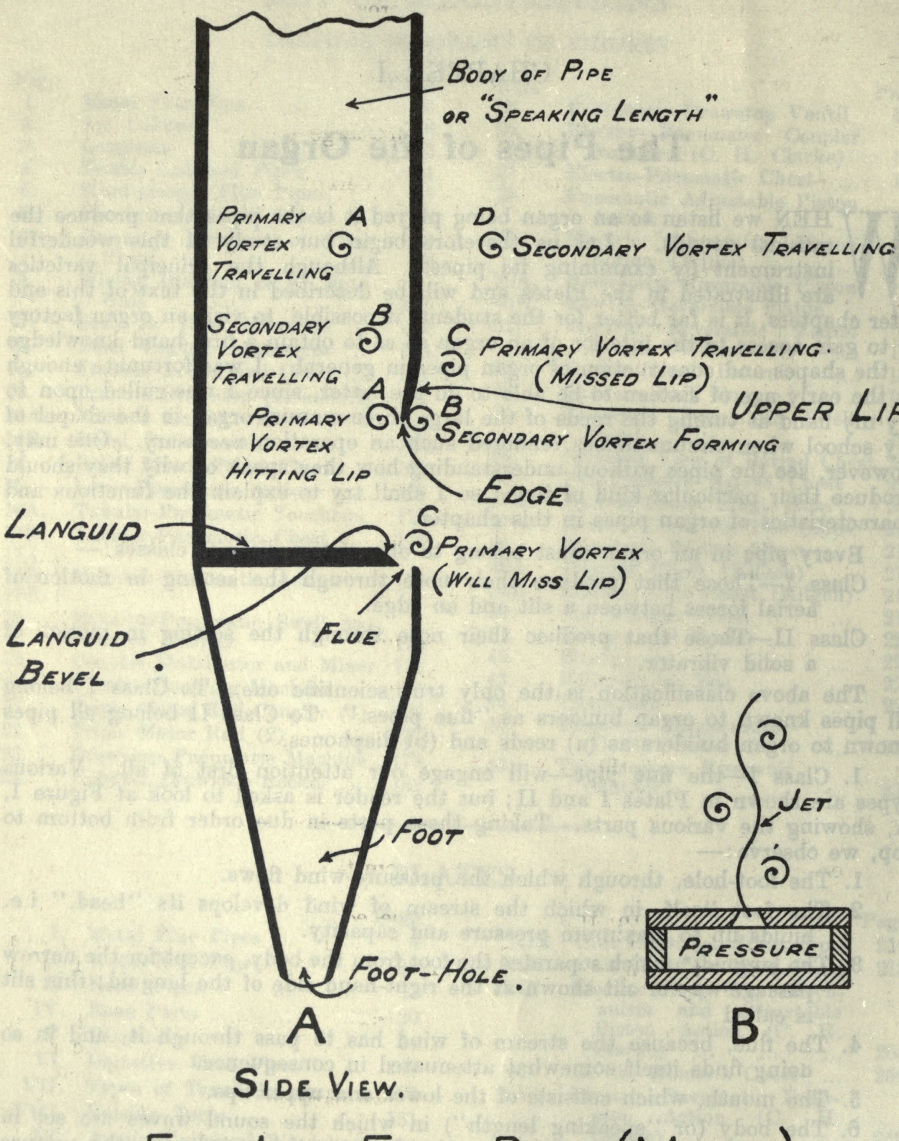

BODY OF PIPE
OR "SPEAKING LENGTH"
PRIMARY VORTEX TRAVELLING
A
D
SECONDARY VORTEX TRAVELLING
B
SECONDARY VORTEX TRAVELLING
C
PRIMARY VORTEX TRAVELLING (MISSED LIP)
A
UPPER LIP
PRIMARY VORTEX HITTING LIP
B
SECONDARY VORTEX FORMING
EDGE
LANGUID
C
PRIMARY VORTEX (WILL MISS LIP)
LANGUID BEVEL
FLUE
JET
FOOT
PRESSURE
FOOT-HOLE
A
B
SIDE VIEW.

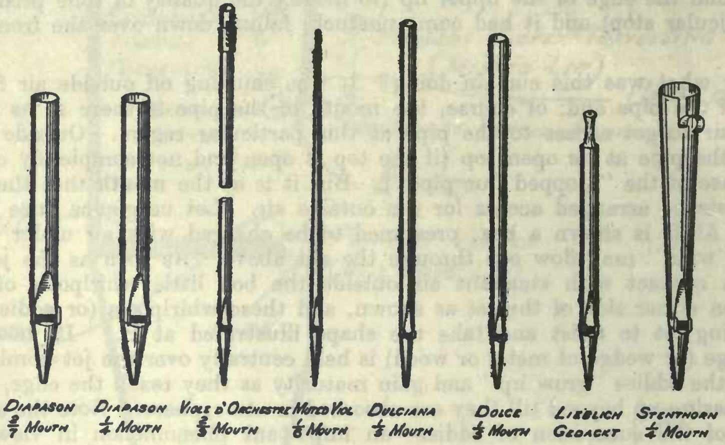
FIG. 1 – FLUE PIPE (METAL)

too high at its bevelled end (e) the upper lip is pushed in (to the left of the illustration) too far, or (f) a curtain is placed across the mouth. These are points every beginner who starts "voicing" organ pipes ought to get into his head first and foremost. From the "Thou shalt not" he will graduate to the "Thou shalt:" a very necessary and salutary experience in the art of learning. With regard to (f), organ builders may scoff and ask where has ever such an obstruction occurred. An organist, about to give a recital on a large and important instrument, discovered to his dismay that middle C on the Open Diapason of the Swell manual was silent—a note much in request during the performance of several items in the programme. As I happened to be present, he asked me if I could ascertain the cause. I expected to find the erring pipe out of its hole, but instead I found that the front of the mouth between the upper and lower lips was completely curtained by a hanging strip of leather. The leather strip had originally been glued round the edge of the upper lip (to modify the quality of tone produced by this particular stop) and it had come unstuck, falling down over the front of the mouth.

Now what was this curtain doing? It was shutting off outside air from the mouth of the pipe and, of course, the mouth of the pipe is there so as to allow outside air to get access to the pipe at this particular region. Outside air also reaches the pipe at its open top (if the top **is** open and not completely closed as in the case of the "stopped flue pipe"). But it is at the **mouth** that there must at all costs be arranged access for the outside air. Let us glance once more at Fig. 1. At B is shown a box, presumed to be charged with air under pressure so that "wind" may flow out through the slit above. As soon as the jet of air comes in contact with stagnant air outside the box little whirlpools of air are formed on either side of the jet as shown, and these whirlpools (or eddies) cause the flowing jet to twist and take the shape illustrated at B. If, however, a sharp edge (or wedge of metal or wood) is held centrally over the jet coming from the slit, the eddies "grow up" and gain maturity as they reach the edge, striking it and passing up beyond till they are absorbed in atmosphere. Note the alternate spacing of the succession of eddies—an important phenomenon in view of the fact that it is only every other eddy that strikes the edge. Now the rapid strokes of the eddies produce a musical note whose pitch or frequency is determined by the number of times per second the eddies hit the edge—if they hit it 520 times a second a whistling sound denoting treble C can be very clearly heard even if the listener is standing some fifty feet away from the apparatus. The frequency of the note depends on (a) the degree of pressure flowing from the windchest, i.e. the pressure of the jet, (b) the distance of the edge from the slit, assuming a central position, and (c) the degree of deviation from the central position given to the edge, i.e. if it is shifted slightly to one side so as not to be exactly in line with the slit.

Now let us look at the flue pipe shown in Fig. I, A. The eddies—or to give them, as I shall in future, their scientific name of vortices—are to be seen curling and whirling their way between the flue and the air column of the pipe-body. There are seven vortices shown, each one at its own particular stage of the journey. The first vortex is formed just prior to the emergence of the jet of air from the flue: it forms gradually and does not attain maturity till it arrives at the upper lip. Here it makes impact, **and gives birth to a child.** This child is called a "secondary vortex," the parent being the "primary vortex." It is the sudden impact or shock against the upper lip that produces the secondary vortex. Meanwhile the parent vortex travels on and up into the body of the pipe followed at a respectable distance (a distance regulated by Dame Nature) by the child. The parent is marked "A" in the sketch, and the child is marked "B." If the vortex system is to be clearly understood it is necessary to realise that there are three aerial conditions collaborating here: (1) the outside stagnant air, (2) the inside stagnant air, sometimes called the "semi-imprisoned air in the pipe," and (3) the air-stream flowing from the flue. It is in this conditioned environment that the vortices have to function and produce what are called the "edge tones." It was until quite recently supposed that the edge tone was produced **solely** by the vortices striking the edge (like taps on a table) at a given frequency per second; but it is now known that the edge tone is also caused by the interaction of the primary and secondary vortices which form two vortex groups, one (the primary) originating at the flue, the other (the secondary) originating at the edge of the upper lip. These two combine to produce a periodic vibration of the wind-stream at the mouth of the pipe from back to front (or in the sketch from left to right). Thus the vortex system, with its own fundamental and harmonics, acts as the originator of the sound produced by the pipe as a whole. Note the **two** rows of vortices generated at the flue: one set hits the upper lip, the other set misses. Both sets have "children" (see secondary vortex "D"). Thus, a "street" is formed by the two progressing rows, and the non-striking row provides a barrier or aerial screen for the inner striking row, otherwise no secondaries could be born.

PLATE I



METAL FLUE PIPES
(ILLUSTRATING PRINCIPAL EXAMPLES)

What, then, happens in the body of the pipe? Here we have a relatively large mass of air (unless the pipe is so tiny that the air column in the body is almost a negligible factor) ready to impose its influence on operations as soon as it is set in motion. The primary and secondary vortices, as we have seen, combine to set in oscillation the air-stream in the mouth about midway between the two lips. This now forces into motion the air column in the body of the pipe so that this column starts vibrating longitudinally up and down the tube in two or more sections according to circumstances. The mass of air in the tube being relatively great, the air column becomes the predominant partner in the business and profoundly influences the mouth tone. Moreover, the "coupling" of the vortex system to the air column is affected by the manner in which their respective frequencies (i.e., fundamental and harmonic) are matched or unmatched. The pitch of the edge tone can be arranged to fall below or rise above that of the column tone within certain limits so as to produce differing qualities of tone from the coupled system; but if those limits are exceeded, the column tone prevails over the edge tone by jumping up to one or other of its natural harmonics.

When the late Hermann Smith stated that the wind-stream abstracted particles of air from the interior of the pipe and then drove the particles back again into the pipe, he was correct as far as his statement went, but he did not know that the said stream cannot oscillate to and fro as it does unless there is something to drive it. On page 45 of his excellent book, "Modern Organ Tuning," he says: "The sole office of the stream issuing from the windway of the pipe is to **exert suction** upon the body of air in the pipe . . . a contest of forces has been set up, between the pulling of the wind-stream and the resistance of the enclosed column of air to being pulled or drawn out." Before I knew anything of the existence of vortices at the mouth I had pencilled in the margin, "It is not explained how or why the wind-stream does **pull** at all: why should it?" We now have the answer to this question.

The voicing of the flue pipe, that is, the process and operation of obtaining the kind of note required from the pipe, is carried out in **practice** by adjusting the pliable and movable portions of the pipe which collaborate to produce the desired result. In **theory,** the art of voicing resolves itself into the appropriate relationship effected between the mouth tone and the pipe tone, assuming a given pressure of wind, a given type of wind generator, and a given size and shape of pipe. In short, if we hand an unvoiced flue pipe to a skilled voicer assuming that the pipe has been made by a skilled pipe-maker, and ask him to do the best he can with it "on three inches of wind and on a barred chest," he will place the pipe on his barred voicing machine, adjust the wind pressure to the three inches indicated by the wind gauge, and "nick the languid."* Then he will measure the correct height of the mouth, i.e., the distance between the lips, by means of a divider, estimating the ratio of the height of the mouth to its width from experience, take a knife and cut up the upper lip to the line marked by the divider point, and test the speech of the pipe by pressing the key of the voicing machine. If the note is too soft, he will enlarge the foot-hole, and test again. If satisfied, he will tap the key several times in succession to see if the pipe speaks promptly or with reluctance, or utters a false sound before giving its true one. If too quick in speaking (in which case it will probably sound an anticipatory note) he will push in the upper lip very slightly **or** he will raise the front edge of the languid very slightly, either of which adjustments will slow down the speech of the pipe. If too slow, he will reverse either operation, pulling out the upper lip or depressing the languid, either of which will quicken the speech. (He may try a little of both operations, if he wishes.) If the note is somewhat feeble in spite of the enlarging of the foot-hole, he may try the effect of slightly widening the flue-passage, or if there is an escape of wind, a breathiness in the tone, he will reduce the width of the flue (between the languid edge and lip edge). If the tone is rather too keen and "edgy," he will either

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* See page 12 for a description of this process.

(a) cut up the mouth a trifle more by paring a strip of metal from the upper lip, or (b) burnish the edge of the upper lip so as to thicken it at the portion struck by the vortices, or (c) reduce the foot-hole by tapping round its perimeter with a chisel. In all three cases he will make the note somewhat softer as well as duller, so that if he wants to preserve the original strength of the note he must open up the foot-hole once more and rely on either or both of the other two operations, (a) and/or (b), to reduce the keenness. There is a fourth remedy open to him, but it must never be tried unless one **knows** from experience that it is a safe expedient, namely, that of deepening the nicks on the languid edge (and/or the lower lip inside edge). Once done, the operation cannot be undone or reversed: hence the need for extreme caution before resorting to it. A summary of the adjustable factors affecting the manner of speech of a flue pipe is now given for reference.

A. To promote dull tone:
1. Increase height of mouth.
2. Pull out upper lip.
3. Press down languid edge.
4. Deepen and/or widen the nicks.
5. Tap up foot-hole.
6. Burnish the upper lip edge.

B. To promote keen tone:
1. Push in upper lip.
2. Raise languid edge.
3. Open up foot-hole.
4. Bevel or sharpen the upper lip edge.

The above summary only deals with the adjustments possible **after** the languid has been nicked and the mouth has been cut up. The voicer has to determine at the outset to what degree these two operations shall be performed, so (if he is wise) he will err on the safe side by making the incisions shallow and cutting the mouth low. But having satisfied himself as to the tonal result of his first sample pipe, he will be able to proceed with greater confidence with the remainder of the series, and will omit many of those experimental steps in the process of voicing which had detained him at the start.

This is not a chapter on voicing, and the above details of flue pipe manipulation by a voicer at his machine are only mentioned in order to show how the various parts of the pipe contribute to the mature note which the pipe is designed to produce. I have said that in **practice** the voicer does this and that, and he can do it with consummate skill and supreme confidence as to the result desired without knowing anything about the actual **theory** of the subject. This, as we all know, is precisely how Art works: it may or may not consciously co-operate with science, though unconsciously the two cannot well contradict each other, since every function of Art is explicable by physical laws even though the operation itself is dictated by hyperphysical promptings. As a matter of fact, the art of voicing is expressed more in the combining of units to make a whole than in the making of the units themselves: thus, we can only really know what a man can do with an organ pipe after he has completed a stop or set of pipes and we are able to play music by means of these pipes. There are no physical laws controlling such a result, since the effectiveness of the whole is something that transcends the sum of its parts. And when we hear an artist-player discussing musical sounds on a stop of artistically voiced and finished organ pipes, we get that wonderful experience of the combination of Art plus Art, which gives us a glimpse of a better world than this physical one.

Have I been guilty of a digression? No, for though we have discovered how the organ flue pipe speaks as an aerial mechanism, we are not in the least assisted by this knowledge in our quest for beautiful tone from that pipe. We now know that a flue pipe is what the physicist calls a "coupled system": that is, the mouth tone is coupled to the body tone, and the two are fused into one mature note. This means that operations altering the area of the mouth affect the spacing of the vortices and their "wave-length," that the degree of wind pressure driving the vortices affects the frequency of the taps on the upper lip, that the "setting" of the lips and languid modifies the direction of the vortex flow, and so on. But voicers may continue to apply their skill to the organ pipe without bothering their heads about vortex activity!

Fig. 1A shows a flue pipe made of metal. A wooden flue pipe (see Plate II) behaves in much the same way as a metal one, except that once made the wooden pipe cannot be so easily modified.* One can alter the size of the foot-hole, cut up the mouth, deepen the notching (or add notching if absent), sharpen or thicken the upper lip edge, or increase the width of the flue by filing or chiselling the upper edge of the cap; but these exhaust all the possibilities, except the addition of such extra devices as the "beard," the "bridge," and "clothing" the flue and/or the upper lip. I shall have more to say about such devices in a later chapter.

Flue pipes can be made with open or closed tops (see Plates I and II which illustrate these). Let us once more examine the open type and see what its vibrating air-column is doing during speech. If the pipe is sounding its fundamental note (e.g., a pipe with a speaking length of two feet sounding middle C), the air column within its tube is divided into two halves: one half vibrates to and fro between the mouth and the centre (approximately) of the tube, the other half vibrating similarly between the centre and the top of the tube. The so-called central point is called the "node," while the open ends of the tube are called "antinodes" (where the wave attains to maximum energy and amplitude). If the pipe is overblown to such a degree that it is unable to speak its fundamental note, it flies up to one or other of its natural harmonics above the fundamental, i.e., to the second harmonic or octave, the third harmonic or twelfth, the fourth harmonic or superoctave, according to the degree of pressure applied to the foot-hole in relation to the height of the mouth and the diameter of the pipe-body. This means that a pipe of relatively small scale with a low cut up of mouth (giving the latter a small area) will overblow to a harmonic more readily than one with a larger scaled body and/or a larger area of mouth. If a hole is bored in the middle portion of the pipe-body, the node is replaced by an antinode and the pipe will sound its octave or twelfth or superoctave according to the pressure applied. When the pipe speaks its octave the air column splits up into three sections with two nodes. Fig. 2A shows the vibrating column of air in the case of a pipe sounding its fundamental note, the length of its tube being approximately half the wave-length of the sound-wave; while B shows the vibrating air column of the pipe sounding its octave. The pipe that speaks its twelfth will have its column of air split up into four sections, and the pipe speaking its superoctave will have five sections. And so on. We have seen that the longitudinal vibrations of the air column in the tube encroach on the mouth region of the pipe, thus taking more or less control of the vortex system; it is equally important to realise that the air column is also debouching on the free atmosphere outside the top of the tube and as a consequence, when in motion, shoots past the point where the tube ends and **tries** to form in the open air above. Thus, the mouth at one end and the air-space beyond the exit of the tube at the other end are "antinodal regions" where the sound-wave should reach its maximum amplitude. At the mouth the vibrating air column meets a certain amount of resistance from the vortex waves, but at the top of the tube it meets with practically no resistance. At this latter point the waves spread out in all directions as they emerge from the tube into atmosphere and thus suffer considerable loss of energy. Another way of viewing the matter is to say that the waves inside the cylindrical tube are "plane" in formation, while after escaping outside into atmosphere they become "spherical," otherwise they would not be audible as sound. This change from plane to spherical is bound to be abrupt if there is no resistance at the point of change or if the tube itself is not so shaped as to make the change more gradual. As, however, we cannot alter the shape of the tube without altering the character of the wave-front, it is clear that the cylindrical tube possesses a defect which is due to its shape. In fact, even the substitution of a conical tube expanding in cross-section from mouth to top does not completely eliminate this particular defect which is common to all open tubes. The inverted conical form of tube does certainly assist the air-waves inside it to emerge more smoothly into atmosphere and it has at various epochs in the history of organ building been much favoured by certain voicers, but the quality of tone produced from such a pipe is fundamentally different from that produced by a cylindrical pipe, so that the voicer must accept this change of characteristic. If the cylindrical tube can be "loaded" in some way so that the emergent sound-waves may

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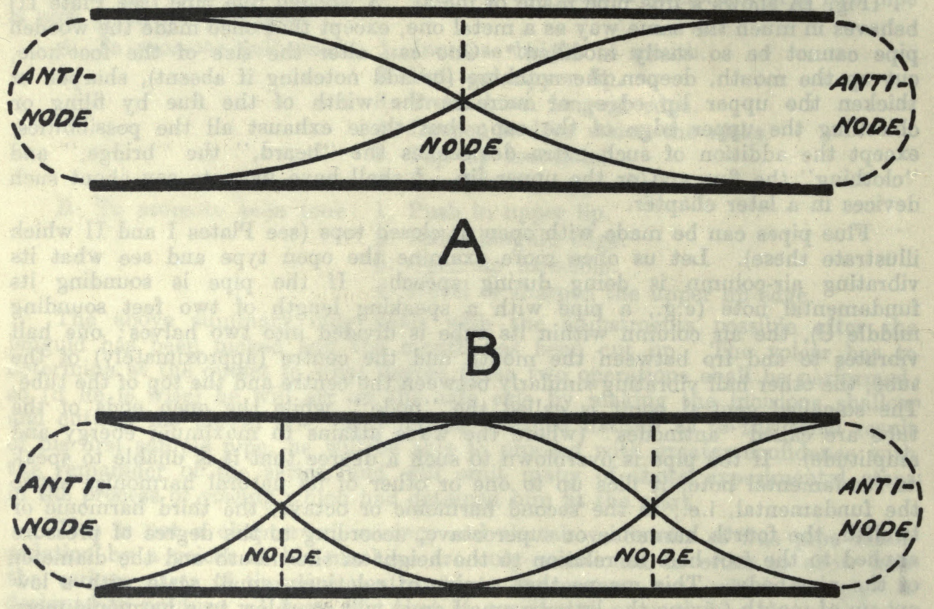
* The "block," which takes the place of the metal languid, is a permanent fixture.

FIG. 2



have something to work against, the antinode can be preserved and the pipe will function with greater efficiency and promptitude. There are three possible ways of doing this: (1) fitting a "cowl" to the top of the tube, a device of my own; (2) fitting an overlapping sleeve or cylinder of suitable length and diameter over the top end of the pipe, a device due to Grindrod; and (3) fitting inside the top of the pipe a cylinder of smaller diameter, part of which protrudes above the top of the pipe, a device due to Mr. Henry Willis. These three appendages are illustrated in Fig. 5. Observe that outside air has access to the top of the pipe, in the case of the "cowl," at the narrow space separating the cowl from the tube on which it rests: this introduces an air-load at the point of emergence and enables the waves to steady themselves and become more stable in their progress to atmosphere outside the top of the cowl. In the case of the Grindrod "tubeon" (Fig. 5B) this induced draught meets the waves from the narrow space between the two tubes, as it does also with the Willis "compensator" at C. Since these devices enable the sound-waves to build up to maximum amplitude and energy with the minimum of loss at the point of emergence, a bigger and richer tone is produced from the pipe, assuming that the pipe has not in the first instance been deprived of its natural series of harmonics by the voicer. It might be supposed that all flue pipes open at the top and cylindrical in shape should be fitted with a device of this kind, but there is a price to be paid to Dame Nature, namely a change of characteristic in the quality of tone produced, and it is not always desirable to have this special quality. There are other ways in which promptness of speech and the intensification of tone can be obtained from an open flue pipe, and the artistic voicer has to exercise his discriminative faculty in the choosing of them.

The question of the correct length measurements of organ pipes now arises, and apart from ascertaining the length by experiment (viz., by making the pipe-body obviously too long and cutting down till the required pitch is at last discovered) there appears to be no foolproof formula that will meet every contingency. The pressure of wind, the temperature of the building, the shape of the tube, the height of the mouth, the presence of such devices as slotting, leathering, bearding, etc., all influence the actual speaking length of a flue pipe. However, it is possible to recommend a formula which does provide, within reasonable limits, a definite guide as to the minimum length for a given pipe. The formula for the speaking length (measured from the edge of the upper lip to the top of the tube) of an open cylindrical pipe whose diameter is not less than 3½ inches at 4 ft. C is

$$L = \frac{\text{speed of sound (ft.)}}{2 \times \text{frequency of note}} - \frac{5}{3}\ \text{diameter of pipe.} \quad \text{in}$$

For pipes less than 3½ in. diameter at 4 ft. C, the formula is

$$L = \frac{\text{speed of sound}}{2 \times \text{frequency of note}} - \text{diameter of pipe.}$$

Here are some examples: (1) What is the speaking length of a diapason pipe sounding CC note at "new Philharmonic pitch," whose scale is 6 in.? The frequency of this note will be 65.5 vibrations per second, and the speed of sound at normal temperature is 1,120 ft. per second. Therefore

$$L = \frac{1{,}120}{2 \times 65{\cdot}5} - \frac{5}{3} \times 6 = 8\text{ ft. }6\tfrac{1}{2}\text{ in.} - 10\text{ in.} = 7\text{ ft. }8\tfrac{1}{2}\text{ in.}$$

Since, however, one has to allow for temperature changes, and also for the voicer's treatment of the pipe, it is necessary to add five per cent. of the "formula length" to the answer, i.e., 7 ft. 8½ in. plus 4½ in. = 8 ft. 1 in. This allows for the usual slot which a pipe of this size invariably has for tuning purposes, as well as for other conditions that may arise.

(2) Next, what is the length of a CC pipe whose diameter is 2¾ in. (other factors as before)? Using the formula we have

$$L = \frac{\text{speed of sound}}{2 \times 65{\cdot}5} - 2{\cdot}75 = 8\text{ ft. } 3\tfrac{3}{4}\text{ in.}$$

Adding five per cent. to the total, we get a length of 8 ft. 7 in.

(3) What is the length, under the same conditions, of a diapason pipe speaking middle C (261 frequencies), whose diameter is 2 in.?

$$\text{Answer, } L = \frac{1{,}120}{522} - \frac{5}{3} \times 2 = 1\text{ ft. } 10\tfrac{1}{2}\text{ in.} \quad \text{Add } 1\tfrac{1}{2}\text{ in., total length} = 2\text{ ft.}$$

(4) What is the length of a viola pipe speaking treble C (522) whose diameter is ⅝ in.? Answer,

$$L = \frac{1{,}120}{1{,}044} - \frac{5}{8} = 1\text{ ft. } 0\tfrac{1}{8}\text{ in.}$$

Add five per cent., and the total length is 1 ft. 0⅝ in.

Having ascertained the length of one pipe it is easy to calculate the relative lengths of the remainder in the series by means of a scale chart (as used by organ builders).

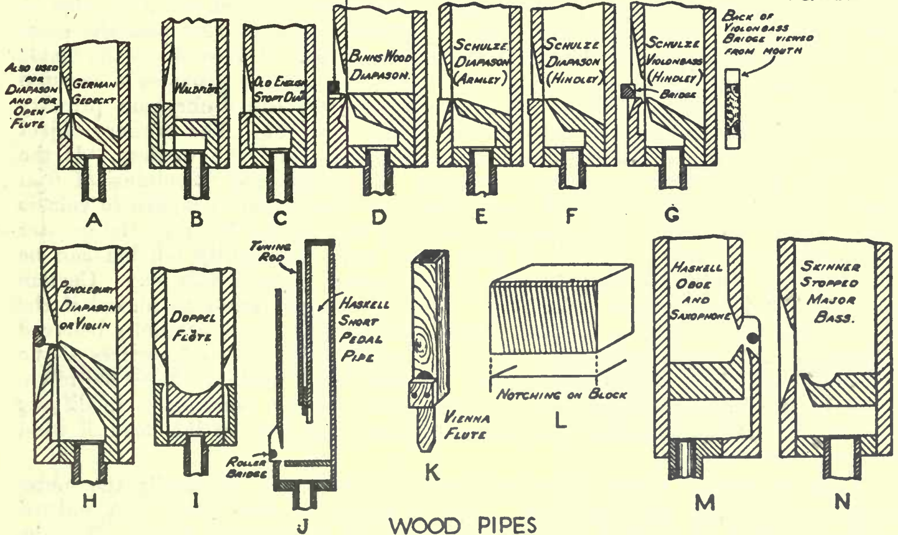
Pipes that taper from the mouth line to the top of the tube are shorter than the corresponding cylindrical pipe at the same pitch, while those that expand towards the top (inverted conical tube) are longer.

The flue pipe can have its top end completely or partially plugged or stopped (see Chapter III), in which case it is approximately half the length of the open pipe when sounding the same fundamental note. The node is at the stopped end and the air-wave is turned back from the stopped end towards the mouth and beyond. The harmonics are generated in the odd series, 1, 3, 5, 7, 9, etc., sounding the fundamental, 12th, 17th, flat 21st, etc. When overblown, therefore, the stopped pipe will speak its twelfth and/or its seventeenth. If the the stopper is perforated, allowing outside air to penetrate in some degree, certain harmonics (notably the third and fifth in the series) are emphasised and produce a slightly reedy quality of tone.

There is one particular appendage to a flue pipe (whether open or stopped) which I have not mentioned, namely the "ears." These are shown in Plate I, and project in front of the mouth at right angles to it on either side. Their object is to shade the mouth from the outer air and assist prompt speech. They are not required for the very small high-pitched pipes, unless the scale is unusually narrow (see Chapter III) as in the case of pipes designed to produce a very keen, stringy tone. It can be realised that on one side the mouth is protected by the pipe-body, while on the other it is at the mercy of the outside air: the ears provide some measure of protection from the outside air and help to restore the balance of pressure to some extent. They also reduce the loss of energy which the vortices are bound to sustain as they reach the upper lip, and at the same time help to preserve the wave-length of the vortex system. Thus, the addition of ears lowers the pitch of the note slightly, and not a few tuners have been known to pinch the two ears closer together so as to shade the mouth more and bring the note into exact tune. The old-fashioned (now practically obsolete) Viola da Gamba was fitted with abnormally long ears for this very purpose so that the pipe, which could not be tuned at the top, might be adjusted by moving its ears towards or away from each other to flatten or sharpen the note.

The ears are, however, necessary for all string-toned pipes, because they serve as supports for the "roller-bridge" which is fitted to them and lies horizontally across the mouth of this class of pipe (see Chapter III). The object of this roller-bridge—sometimes called the "frein" (French for curb), and sometimes wrongly called the "beard" (see Chapter IV)—is to prevent the narrow-scaled pipe from speaking its octave or its twelfth instead of its fundamental. If the pipe is so blown as to speak a harmonic above the first, the application of the roller-bridge **at the correct spot** in front of the mouth will bring its note back to the fundamental; and if the pipe is of narrow diameter ("small-scaled") it will also continue to sound the upper harmonics very richly in addition to the fundamental. Thus, the invention of this appliance was a revolutionary step in the history of organ tone. It made possible the voicing of string-toned stops without that irritating slowness of speech which characterised all examples previously. Scientifically the device is an "obstacle" pushed in front of the vortex waves at the mouth. What actually happens is that the distance between the two rows of vortices (the "street") widens as the pressure (and volume) of wind is increased. A condition then arises when the vortices are no longer able to maintain their position and are forced to revert to their original narrow spacing with twice the number progressing between lower and upper lips. The pitch of the note then jumps up to the octave above the original note. The application of the "obstacle" or

PLATE II


Also used for Diapason and for Open Flute
German Gedeckt
A
Waldflöte
B
Old English Stopt Diap
C
Binns Wood Diapason.
D
Schulze Diapason (Armley)
E
Schulze Diapason (Hindley)
F
Schulze Violonbass (Hindley)
Bridge
G
Back of Violonbass Bridge viewed from mouth
Pendlebury Diapason or Violin
H
Doppel Flöte
I
Tuning Rod
Haskell Short Pedal Pipe
Roller Bridge
J
Vienna Flute
K
Notching on Block
L
Haskell Oboe and Saxophone
M
Skinner Stopped Major Bass.
N

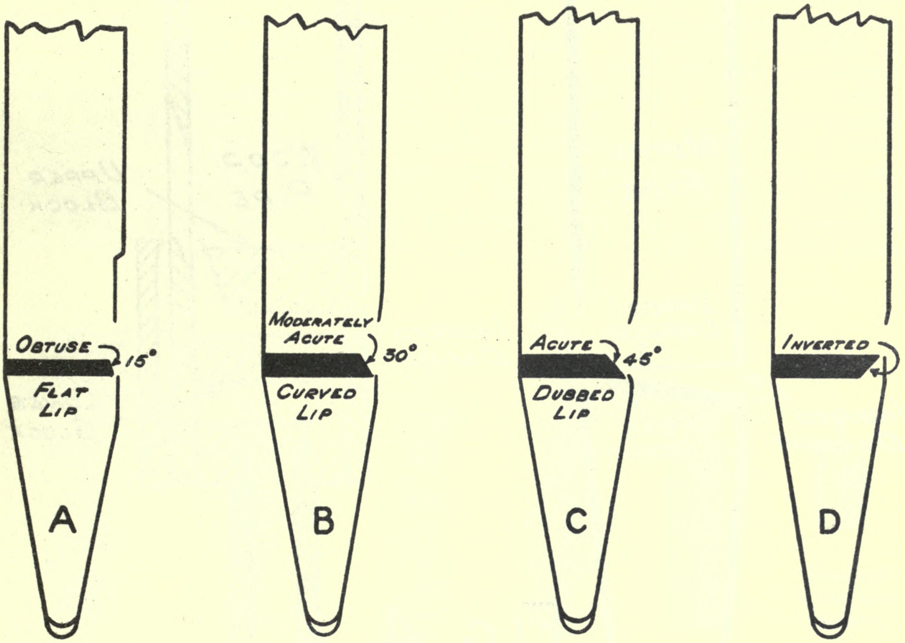
WOOD PIPES

bridge deflects the wind stream on to the upper lip, and the vortices return to their original number with the **wider spacing** and thus the fundamental note is restored. The increased pressure (and volume) of wind imparts more energy to the aerial mechanism, both at the mouth and in the air column in the pipe, with the result that the upper harmonics are well in evidence along with the fundamental.

I mentioned earlier in this chapter the "nicking" of the languid of a metal pipe and the "notching" of the block of a wooden pipe. I shall have more to say about this process in the chapter on voicing, but a few words about its influence on the speech of the pipe seem called for. The nicks are small incisions made by a special tool (or "nicker") and resemble the teeth of a saw in appearance. These incisions are made on the lower edge of the languid bevel, and may also be made on the inside edge of the lower lip. In the case of a wooden pipe the nicks or notches are cut on the front edge of the block and also (if desired) on the inside flat top surface of the cap (see Plate II). Thus, the nicking provides a serrated flue-passage or windway which the wind-stream and the embryonic primary vortices have to pass through on their way to the upper lip. The primary object of nicking is to reduce the energy of the wind-stream and the vortices. If the pipe is not nicked it will generate a number of high-pitched harmonics at first speech prior to sounding its proper note: this unmusical sound is known to voicers as the "buzz" or "spit," and generally speaking the smaller the pipe the greater the tendency to "buzz." Pipes of large scale and very lightly winded can be un-nicked, and Father Smith produced many diapason pipes in this way. Certain types of wood pipe are also not nicked, while other types **must** be nicked if the objectionable "spit" is to be eliminated from their speech. It is generally believed by physicists that these small incisions set up correspondingly small vortices at the flue which interfere with the primary vortices and weaken them at birth. Whatever the explanation, the fact remains that nicking exercises a modifying effect on the higher harmonics and also a damping influence on the head of wind emerging from the flue.

There is another device which is applied to flue pipes, especially the metal variety, which must be mentioned. This is known as the "slot." A narrow rectangular piece of metal is cut out from the top of the pipe at the side, the distance from the top being usually that of the pipe's diameter. The width of the slot may be anything from a sixth to a third of the pipe's diameter according to the voicer's fancy. It is usual to fit a cylindrical tuning slide round the top of an open metal flue pipe (see Chapter on Tuning), and in the case of a slotted pipe the slide is placed below the top of the slot so that the bottom portion of the slot is covered and a portion of the top left exposed. The slot enables outside air to make contact with the air column at the antinodal region just prior to the arrival of the wave at the top and so modifies its shape; but, the pipe being cylindrical, there is bound to be an abrupt change from plane to spherical in the wave-form, which means that certain harmonics are emphasised at a particular zone in the series. These harmonics are the 8th, 9th, 10th, 11th, 12th and 14th, of which the 8th, 9th and 11th predominate, being almost equal to the 3rd and 4th in amplitude. If the pipe is quite small in scale (relative to its length) the effect of the slot is to produce an increase of pungency; while a larger scaled pipe gives a "horny" quality of tone as the result of the prominence of the 4th, 5th, 8th and 9th harmonics. The narrower the slot the higher the harmonics thus emphasised, and also the less audible: a wide slot, such as a "third of the diameter," produces the greatest number of emphases in the zone above referred to, while a slot of still wider cross section transfers the emphasis to the lower part of the zone. Many modern voicers, of whose number I am one, dislike slotting and prefer to obtain the result aimed at by other means. In Chapter III I shall have the opportunity of setting out in greater detail the *modus operandi* of "string voicing."

The reader will remember that my experience of the "curtain" of leather which I found gagging the middle C pipe of a famous organ (which, unfortunately, did not survive the war) was due to the fact that the upper lip had been coated with a sheet of leather. This is a device practised by some voicers with the object of ensuring a "smooth, round tone" from the pipe so treated. The leather is usually thin "splitskin" and is glued round the edge of the upper lip so that part of the sheet is seen covering the upper lip outside and the other part is on the inside and therefore invisible. The effect of the leather is to present a soft surface for the impact of the vortices, with the result that their energy is damped and the higher harmonics are consequently attenuated. The introduction of higher pressures of wind created a fresh set of problems for the voicer of flue pipes, who found that cutting up the mouth higher to suit the increased pressure did not solve the problem adequately; so the idea of covering the edge of the upper lip



Old Type — Transitional Type — Modern Type — Inverted Type

Fig. 3 - Metal Pipe Languids and Lips

with soft material met with considerable approval in certain factories as a way out of the difficulty. If, for instance, the mouth is too high and the note is "windy," the leather sheet will slightly lower the mouth and at the same time soften the blow of each vortex, which is equivalent to a lowering of the pressure. But, of course, the note is changed in character and a diapason so treated becomes a different kind of diapason, so that the solution of one set of problems introduces (as happens so often) another set in its train.

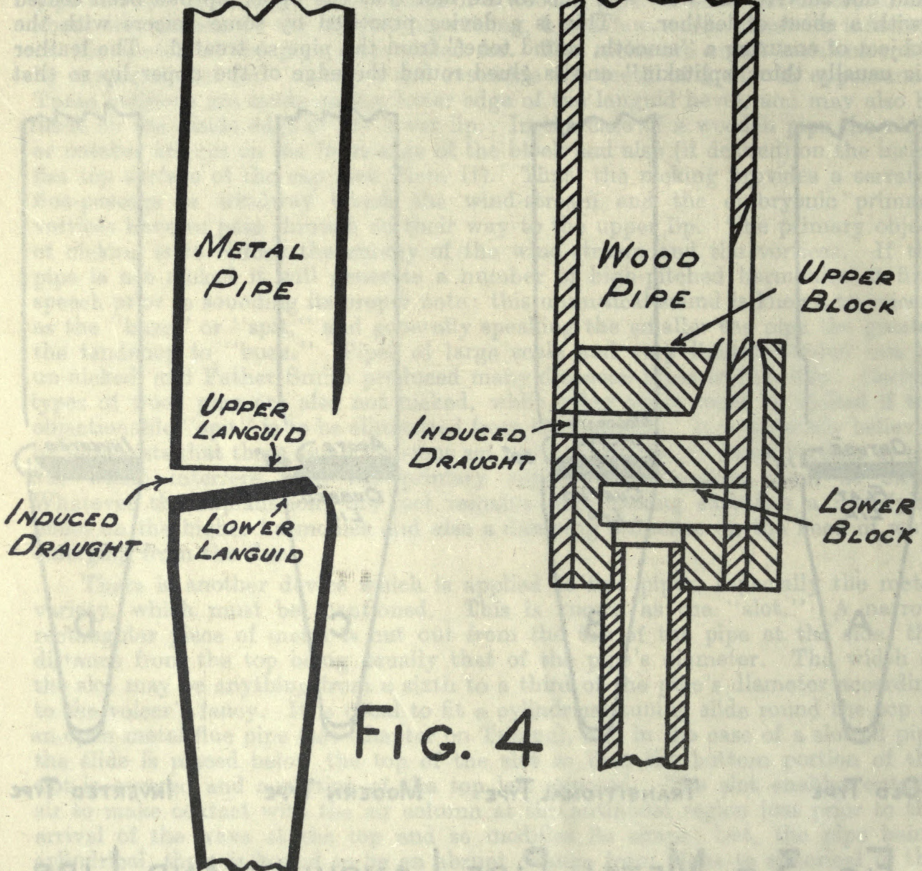


FIG. 4

Finally, there is the "languid" to be considered. This important member of the flue pipe is now made as shown in Figs. 1A and 3C, but the earlier builders favoured a less acute-angled bevel as shown in Fig. 3A. There is in addition as shown at 3B a transitional type of bevel, less acute than at 3A and less obtuse than at 3C. The languid can be inverted as in Fig. 3D; while in Fig. 4 is shown a "double languid" (invented by Vincent Willis). If the bevel is acute as in Fig. 1, the energy of the vortices is greater than is possible with the obtuse bevel in Fig. 3A, so that a pipe fitted with an obtuse-bevelled languid is not suitable for keen, stringy tone. If, however, it is desired to reproduce the reposeful and rather sombre tone of the old builders the obtuse-bevelled languid is essential, for this is the type of languid they employed. The inverted languid does not favour either keen or dull tone as such: it is entirely neutral in its effect. Consequently it may be used for pipes producing almost any of the main categories of tone, diapason, flute or string. The top surface and edge of this languid must lie flush with the edge of the lower lip, and no nicking is admissible. The effect of the double languid is very similar to that of the antinodal sleeve mentioned earlier in this chapter: that is, it affects the antinodal wave-form at the mouth in much the same way as the sleeve does at the top of the tube. The hole pierced in the back of the pipe opposite the mouth induces a draught of outside air (just as the slot does at the top of the pipe) at a vital spot. The result is a considerable increase of energy in the air-wave front forming at the mouth and also a prompter coupling of the vortex and air column systems at first speech. The tone is intensified in power and richness so that large scaled pipes can be employed with a moderate wind pressure for the production of big, bold tone. The price to be paid, however, for the increase of volume and harmonic content is a certain harshness of quality which tends to engender a feeling of irritation, if listened to for any length of time.

The languid of the wooden flue pipe is usually called the "block," as already pointed out (probably because it cannot be shifted). It can be altered in shape before being fitted to the pipe. The top surface, for instance, may be horizontal or else inclined downward towards the rear of the pipe, or may be cut away from the mouth edge so as to leave only a narrow strip of wood for the nicking. The front portion of the block may be vertical, or it may be bevelled in a backward direction. In the latter case it is designed to encourage the upper harmonics. The "cap" of the wood pipe takes the place of the lower lip of the metal pipe and is either glued or screwed on (preferably the latter). This also can be variously

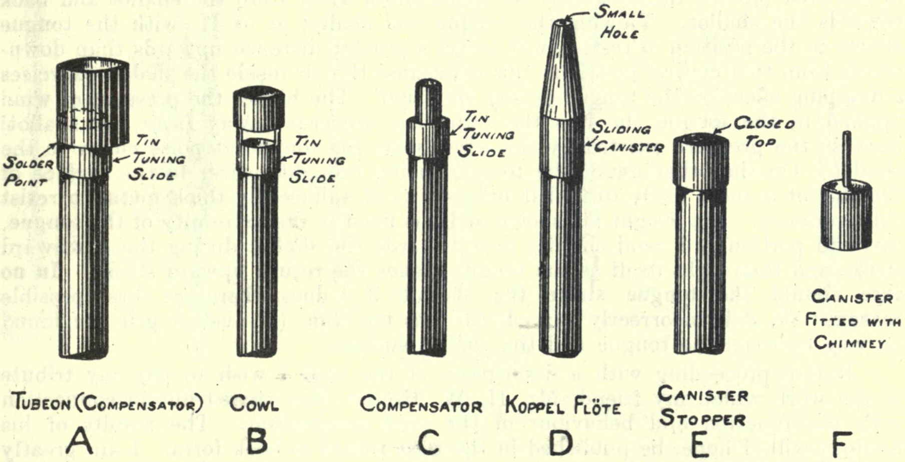


Fig. 5

FLUE PIPE HEADPIECES.

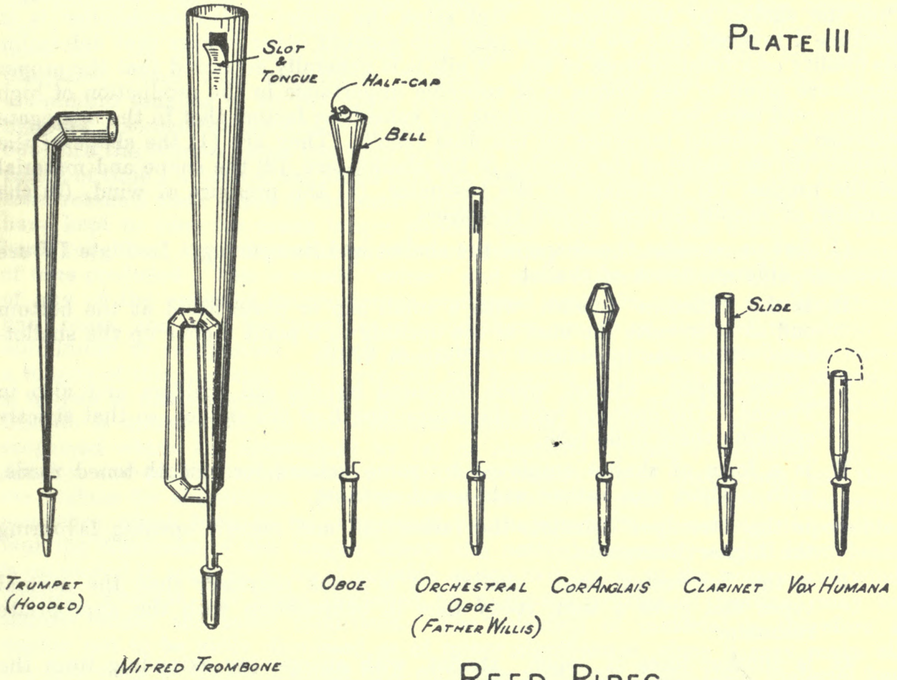
shaped so as to be flat inside or hollowed out, with the upper inside edge either vertical or slightly bevelled. The top edge of the cap may be either flush with the top edge of the block (in which case no nicking is required), or it may be set slightly below the top edge of the block (in which both block and cap are usually nicked). Various types of wood pipe are illustrated in Plate II.

II. Having examined the first class of organ pipe, namely the flue pipe, we come now to the second class of organ pipe represented by the reed and the diaphone. The basic difference between the reed and the diaphone lies in the type of vibrator employed, but whereas the originator of the sound produced by the flue pipe is the aero-dynamic system established between the flue and the upper lip, the originator of the sound produced by both the reed and the diaphone pipe is a vibrating *solid*.

The **reed pipe** will now claim our attention. Plate IV shows the various parts of this pipe, and it will be seen that the mechanism of this sound-producer depends for its function on a vibrating lamina or flexible bar of metal stretched along the surface of a small barrel-shaped resonator (called the "shallot"). The lamina is called the "tongue" and at one end is clamped by means of a wedge to the tip of the shallot while at the other end it hangs free in mid-air and flush with the "head end" of the shallot. The relative positions of tongue and shallot are clearly shown at A and at H. The tongue is curved so that it shall increase its distance from the top surface of the shallot gradually from the tuned point indicated at H*b* to the extremity at *c*. When pressure-wind is introduced through the bore of the boot (see A) the tongue is set in vibration away from the shallot and back towards the shallot. Viewing the tongue and shallot as at H, with the tongue shown in the position of rest, it will travel a greater distance upwards than downwards from that central position: this is because the air inside the shallot exercises a damping effect on the tongue during vibration. The higher the pressure of wind applied to the tongue the less the excursion upwards (away from the shallot) because the pressure exerted by the wind holds the tongue at poise closer to the shallot. On the other hand, the tongue, being brought nearer to the surface of the shallot is more likely to foul it unless it is of sufficiently thick metal to resist this tendency. If a weight (as shown at H) is fixed to the extremity of the tongue, this end portion will bend slightly over towards the shallot during the downward stroke and then right itself as the tongue makes the return upward stroke. **In no case should the tongue strike the shallot**: if it does, there are three possible reasons: (1) it is incorrectly curved, (2) it is too thin, (3) dust or grit has found its way between the tongue and the shallot surface.

Before proceeding with a description of the reed I wish to pay my tribute to the work which my friend, Mr. H. W. Homer, has carried out in connection with the function and behaviour of the reed mechanism. The results of his findings will, I hope, be published in the near future in book form. I am greatly indebted to him for much important information not to be found in any text-book. Such data as I am able to present to the reader in these pages are derived from my own personal experience and confirmed by Mr. Homer's experiments. In one or two small points Mr. Homer has been able to correct me, for which I am duly grateful. For example, it is mentioned in certain text-books on sound that the reed executes S.H.M. ("simple harmonic motion"), which presumes that it produces a "sine wave." I naturally accepted so authoritative a statement; but it is quite incorrect. The air-wave produced by the vibrating tongue in the shallot and through it to atmosphere is "flat-topped," which represents a considerable deviation from S.H.M. In fact, it is due to this particular shape of wave that the characteristic quality of the reed pipe emerges, the first eight harmonics being produced at more or less equal amplitude. Another point is that the curvature of the tongue is not truly parabolic as is generally supposed; that is, if the tongue is properly curved it does not vibrate in this manner and therefore has to be curved so as to compensate for the uneven forces caused by the wind pressure. The thinner the tongue the more readily is it upset by these uneven forces. The pressure varies all along the length of the tongue: it is at its maximum at the head of the opening in the shallot-face and at its minimum at the point of the tuning-spring where the opening tapers to its close. Even if the shallot has a parallel-sided opening the pressure varies in similar manner though it is less reduced at the spring-point. The technique of curving the tongue is described in the chapter on

PLATE III



REED PIPES
(ILLUSTRATING PRINCIPAL EXAMPLES)

Voicing, as are other details connected with the treatment of reed pipes. As regards the material used for tongues, brass is easily the favourite, though other materials can be used such as bakelite, aluminium, steel, and even wood. I possess a reed pipe, made by Mr. Homer, which is **entirely** constructed of wood: there is not a metal part in it except the tuning spring. It is two feet in length, with an expanding resonator, and produces the tone of a tromba. The object of making the pipe completely of wood was to prove that the **characteristic** reed quality does not depend on the material of which the various parts are constructed, as is usually imagined.

How is the sound produced in the vibrating reed system? The tongue, by intercepting the flow of wind under pressure, creates shocks of air in the boot and sends these pulses into the shallot. Since the shallot has an opening with three edges, vortices and edge-tones are produced (as in the human larynx). The edge-tones are amplified by the air column in the shallot, and the coupled system is again coupled to the air column in the resonator. (The resonator or tube is shown in each of the reed pipes illustrated in Plate III: it is soldered to the top of the block where the hole is shown in Fig. 3A, or else, in the case of the larger pipes, it is fitted into the shank). If the resonator is removed (as in Fig. 3A) the note emitted by the shallot is plainly audible though not very pleasant: the addition of the resonator makes a very noticeable difference and also lowers the pitch of the shallot-note. Basically, therefore, the note is produced by the air pulses released into the shallot by the vibrator. But since the object of the mechanism is to produce a musical note we have to take into account other factors that determine its quality as a finished work of art. While it is generally conceded that the proper curvature given to the tongue is of supreme importance in the production of high quality reed tone, we must not overlook the subsidiary factors that in the aggregate exercise a profound influence on the final result. They are (1) the shape of the shallot, (2) the shape of the opening in the shallot-face, (3) the shape and material of the tongue, (4) the shape of the resonator, (5) the pressure of wind, (6) the addition of various devices known to voicers.

(1) Let us consider the shape of the shallot and its opening. In Plate IV are given six different types of shallot.

B is the "filled-in" shallot, with a small cap or plate fitted at the bottom end so as to raise the base of the opening to a point higher up the shallot-face. This was introduced by Vincent Willis.

C is the "open" shallot, much favoured by the old builders and also in France. The opening runs the entire length of the shallot, so that strictly speaking there is no face.

D is a form of shallot employed by some voicers for smooth-toned reeds, with a short and rather wide-based opening.

E is the "trumpet" shallot, the rather tall and narrow opening favouring the higher harmonics.

F is the "orchestral oboe" shallot: it is much narrower than the normal types and gives a thin, reedy tone in conjunction with the appropriate resonator.

G is another form of "open" shallot, with an opening extending from the base right to the top, but in this case the sides are not parallel as at B but slightly converging. For the production of fiery trumpet tone this type of shallot is much in demand.

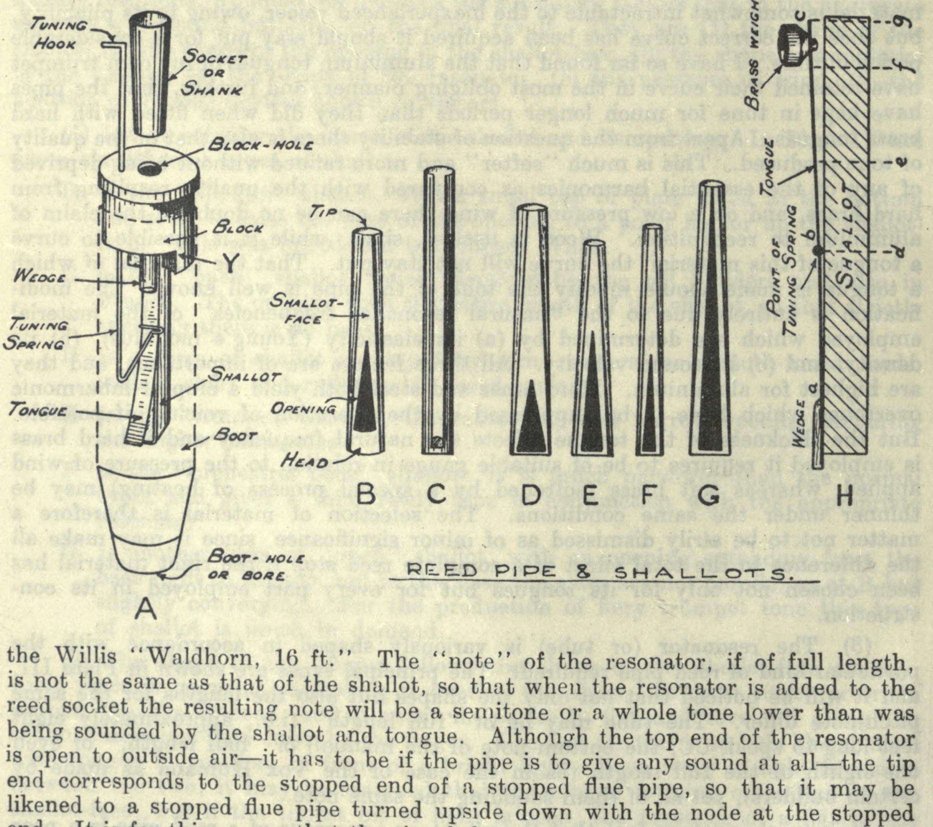
(2) The shape of the tongue follows the shape of the shallot-face exactly, since there is no point in making it overlap the sides. It must never protrude beyond the shallot-head, and it must lie perfectly flat and level all along the shallot-face when held down by the finger. The test for this is to hold the shallot, with tongue in position, in front of a bright light: if no trace of light is visible between the two, it may be assumed that the tongue is lying quite flat on the shallot-face; but if the tiniest bit of light is seen, the presence of a flat in the tongue is indicated, which means that the tongue is not properly curved at that point. In Plate IV at H a weight is shown attached to the end of the tongue.

The object of the weight is to slow down the vibrations of the tongue and so lower the pitch of the note: in which case the position of the tuning spring can be transferred to a point nearer to the base. The weight in addition to lowering the pitch damps the vibrational sensitivity of the tongue so that the higher harmonics are somewhat attenuated. This device was introduced by Father Willis, though it had previously been applied by German builders in the form of lumps of solder dropped on the ends of the long tongues of pedal reeds. The material employed for tongues is almost invariably sheet brass, though there is considerable divergence of opinion in the trade as to the comparative merits of hard and soft brass. I have tried various kinds of metal, including stalloy and steel, but the results have not justified their use. My friend, Mr. C. Horace Clarke, however, has employed hard-rolled aluminium sheet for the tongues of the top octave of the 4 ft. reed ("clarion") with great success, and I believe he is the first to have done so. He very kindly supplied me with the top pipes of my trumpet at Stagsden, fitted with aluminium tongues, and I thereupon proceeded to fit aluminium tongues to all the lower pipes of this stop as far as middle C. This material is somewhat intractable to the inexperienced voicer, owing to its pliability, but once the correct curve has been acquired it should stay put for a considerable period of time. I have so far found that the aluminium tongues of my own trumpet have retained their curve in the most obliging manner, and further, that the pipes have kept in tune for much longer periods than they did when fitted with hard brass tongues. Apart from the question of stability there is also that of the quality of tone produced. This is much "softer" and more refined without being deprived of any of the essential harmonics as compared with the quality resulting from hard brass, and on a low pressure of wind there can be no doubt of the claim of aluminium to recognition. Wood is useless, since, while it is possible to curve a tongue of this material, the curve will not stay put. That the material of which a tongue is made should modify the tone of the pipe is well known. The modification is entirely due to the "natural resonance frequencies" of the material employed which are determined by (a) its elasticity (Young's modulus), (b) its density, and (c) its sound velocity. All three factors are of importance, and they are highest for aluminium. Hard brass and steel both yield a crop of inharmonic overtones which have to be suppressed by the operation of voicing, if possible. But the thickness of the tongue affects the natural frequency and if hard brass is employed it requires to be of suitable gauge in relation to the pressure of wind applied, whereas soft brass (softened by a special process of heating) may be thinner under the same conditions. The selection of material is therefore a matter not to be airily dismissed as of minor significance, since it may make all the difference to the total effect of a complete reed stop if the right material has been chosen not only for its tongues but for every part employed in its construction.

(3) The resonator (or tube) is variously shaped in accordance with the particular kind of reed pipe required. The principal types are shown in Plate III, and it will be noticed that not only the shapes but also the lengths for the same pitch-note differ. The tube may be of "full length" (i.e., approximately eight feet long to speak CC, the bottom note of the manual) or "half length," or even one-eighth of the full length (as in the case of the Vox Humana as made by certain builders), yet all of them sounding the same note.

It is an elementary fact that the vibratory apparatus of a reed pipe is a poor and feeble affair by itself because the air pressure energy in the shallot is quickly dissipated on reaching the air outside. The resonator is therefore a necessity and is fitted to the block-hole (or the socket in the case of the larger pipes). From this point it must start with a narrow cross-section (known as the "tip") and should never be much wider than the corresponding tip of the shallot. This is clearly illustrated in the examples shown in Plate III. But it must expand from the block-connection a certain distance even if a cylindrical tube is fitted as in the case of the clarinet and vox humana pipes. The other types of reed pipe have a tube which is inverted conical in shape and commencing at the tip with a narrow cross-section. Many of the reeds made by the Victorian builders prior to the advent of Father Willis on the scene had tips which were too wide, with the result that the tone was rough and strident. A wide tip fails to control the shallot tone adequately and the inharmonic overtones of the reed mechanism are allowed free rein in consequence. In certain types of reed the diameter of the shallot tip (inside) is the same as that of the resonator tip (inside), a notable example being the Willis "Waldhorn, 16 ft." The "note" of the resonator, if of full length, is not the same as that of the shallot, so that when the resonator is added to the reed socket the resulting note will be a semitone or a whole tone lower than was being sounded by the shallot and tongue. Although the top end of the resonator is open to outside air—it has to be if the pipe is to give any sound at all—the tip end corresponds to the stopped end of a stopped flue pipe, so that it may be likened to a stopped flue pipe turned upside down with the node at the stopped end. It is for this reason that the tip of the resonator is so sensitive to variations made in its size. Moreover the very slightest leakage at this point, for instance at the solder-point between block and tube, ruins the tone. The material of which

PLATE IV


TUNING HOOK
SOCKET OR SHANK
BLOCK-HOLE
BLOCK
Y
WEDGE
TUNING SPRING
SHALLOT
TONGUE
BOOT
BOOT-HOLE OR BORE
A
TIP
SHALLOT-FACE
OPENING
HEAD
B
C
D
E
F
G
BRASS WEIGHT
c
g
f
TONGUE
e
POINT OF TUNING SPRING
b
d
SHALLOT
WEDGE
a
H

REED PIPE & SHALLOTS.

the tip is made is also a factor of importance: it must possess a low sound velocity (not more than 3×10^5 cm. per sec.), so that zinc is useless here. A resonator may be made of zinc provided that the tip portion is of "organ metal" (an alloy of tin and lead), the two portions being soldered together to form the complete tube. Even so, the smaller pipes of a reed stop must never be made of zinc, since the natural resonance frequencies of zinc are inimical to good results and cannot be eliminated by any known voicing method. For the larger pipes, where a tone more or less free from the higher harmonics is aimed at, it is possible to mask these undesirable overtones by the application of certain voicing devices, while in the largest pipes, e.g., the pedal reeds of 16 ft. pitch and lower, the large mass of air in the resonator effectually inhibits the natural frequency characteristic of the metal employed, provided that the tip portion of the tube is made of the correct material.

The harmonic series of a conical tube is even, while that of a stopped cylindrical tube is odd. All reeds, therefore, except those producing tones from which the even harmonics are intended to be absent (such as the clarinet and vox humana) are fitted with inverted conical tubes (barring reed pipes of special construction and giving abnormal tones). The scale of the tube, that is the diameter at the top end, is of great importance, since it determines to a large extent the effect of the resonator on the reed note. Generally speaking, a small scale favours the development of the higher harmonics, while the larger scale can only do so if the power of the note is increased at the same time. The beautiful "ringing quality" associated with the Willis chorus reed is quite unobtainable from reed tubes of large scale: that is, there is a definite limit to the diameter at the top of the resonator which must on no account be exceeded if this particular type of tone is to be produced, although the shape of the tube is by no means the only factor to be taken into consideration by the voicer. The real reason why excessive scales are unfavourable to the production of "good chorus reed tone" is the presence of inharmonic overtones in a wide cone closed at one end. On the other hand, it would be a mistake to go to the opposite extreme and employ too narrow a tube. There are artistic limits in either direction, though, of course, for the production of a special effect not intended for general use one may infringe all the canons of art!

While it is possible to obtain the same pitch of note from a resonator of full length, half, third, fourth or eighth length (apart from the question of tonal quality), there is very little margin allowable to the voicer in the deviation from a given length for fine adjustment. But there *is* a margin, and it is quite sufficient, narrow as it is, to provide pitfalls to the beginner. In other words, a reed can be tuned to give a dull or a keen note (within limits) by slightly altering the relationship between the note of the tongue and that of the tube. If this tube is a little too long for the shallot-note, the tone loses harmonic content, and vice versa, the tone gains in harmonics. (See the chapter on Voicing.) The matching of the two systems is a matter for the skilled voicer and is largely determined by ear. That is, a voicer may know how to couple the tube note to the reed note, yet may choose the wrong coupling through sheer lack of aural discrimination. I should say that this is the commonest fault to be found in the actual finishing of organs, and I shall have more to add on this subject in a later chapter. If the tube is unduly lengthened in proportion to the vibrating length of the tongue (determined by the position of the tuning spring) the note becomes gradually weaker and duller till at length it flies up to a harmonic and refuses to speak the fundamental pitch-note till the tube is shortened. If the tube is unduly short, the note develops harmonics at an alarming rate until the tube is reduced to a point representing a fraction of the full length such as three-quarters or half, in which case the quality is less disagreeable, but only because it has changed its character and settled on to a higher harmonic basis. Slight adjustments of the length of the tube are made more convenient to the voicer and tuner by means of a "slot" (shown at the top of the tube of the "mitred trombone" pipe in Plate III). The projecting strip of metal (the "regulating tongue") is pushed in or pulled out as required. The tops of reed tubes are often turned at right angles as shown in the "trumpet" pipe in Plate III. This is known as "hooding," and prevents dust from falling down the pipe and finding its way between the tongue and the shallot-face. (But dust and dirt can get there from the fan blower unless the intake to the blower is protected by a strip of gauze). Hooded pipes should be well stayed up; in many organs I have seen the tubes of some of the reeds lying face down on the soundboard, having snapped clean off at the tip through being top-heavy. When the pipe is very long and height is a consideration, it is customary to "mitre" the tip of the tube as shown in Plate III.

(5) The degree of wind pressure applied to the tongue through the hole in the boot is varied by organ builders between a minimum of 2½ in. and a maximum of 25 in. according to the result aimed at. At Liverpool Cathedral Mr. Willis used a pressure of 50 in. (the highest in this country) for the "tuba magna," while in the mammoth 1400 stop organ in the Atlantic City Auditorium (U.S.A.) there is a tuba standing on 100 in. pressure. But these are two exceptional cases. It may be asked what the actual difference is between low and high pressures for reed pipes. Obviously, a high pressure would be employed for the production of a tuba, which is the most powerful of the reed tribe. If it is desired to obtain a powerful tone with a goodly percentage of fundamental and at the same time to preserve the essential refinement of quality without sacrificing the harmonic colouring of the mature note, then there is a minimum of pressure by means of which this result can be achieved. One cannot, for instance, produce certain types of chorus reed tone on a low pressure of wind, and similarly one cannot produce certain other types on a high pressure. The recognition of this simple but basic fact is of supreme importance to the modern reed voicer, but it is not every voicer that is aware of it. The pressure of wind measured by means of a wind-gauge placed over a soundboard hole (in place of the pipe that would be standing there) is in all cases higher than the actual pressure of wind that operates the reed mechanism in the boot. This is due to friction in the boot-hole and the admission of outside air from the top of the pipe and shallot. The pressure also varies as the tongue opens and closes the shallot orifice. To give an example (from Mr. H. W. Homer's research notes), if the pressure from the windchest is five inches of water, and is applied to a CC reed pipe through a boot-hole of 1.18 cm. diameter, the pressure with the tongue fully open is 3.3 in. (i.e. 66%): with the tongue half open it is 3.7 in. (74.1%): with the tongue a quarter open it is 4.4 in. (88.2%). The pressure shows a progressive decrease along the vibrating tongue from the head of the shallot to the point where the tuning spring is set. It is a good rule to make the boot-hole or bore the same size as that of the shallot-head, where it is desired to obtain the maximum degree of pressure in the boot.

(6) Lastly, there are certain devices employed by voicers which influence and modify the quality produced from reed pipes. The fixing of weights or loads to the end of the tongues has already been mentioned. Leathering the shallot-face in order to smooth out any undesirable harmonics has been called "the last

resource of an inefficient voicer.'' It is a practice to be discouraged, since even for the production of French horn tone it is quite unnecessary. I have known cases of professional voicers applying French chalk to the shallot-face and the tongue under the illusion that the ''rattle'' in the lowest octave of a trumpet would be disposed of. Further ''flats'' were added to those already present with the result that the ''rattle'' was increased. But assuming the correct curvature of the tongues, it is quite permissible to employ certain devices for the production of certain types of tone. Those most commonly used are:

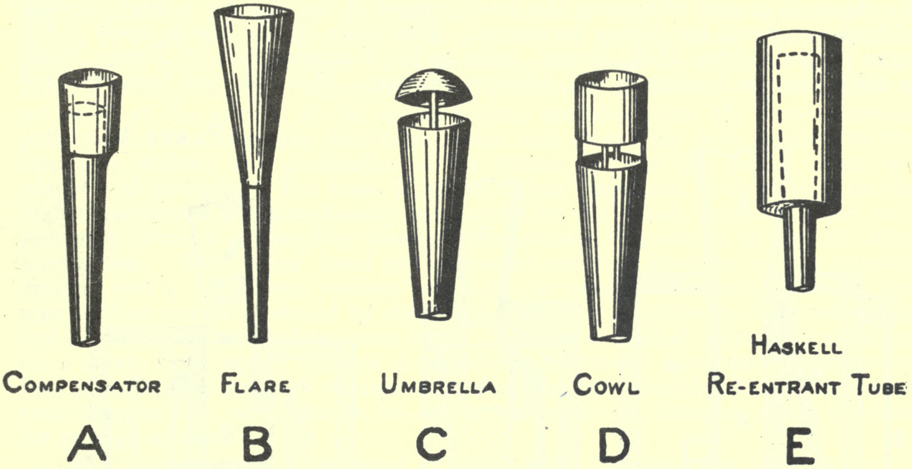


Fig. 6

REED PIPE HEADPIECES.

(a) the ''bell'' (see the Oboe pipe in Plate III) which is a short inverted cone soldered on to the top of a narrow main tube;

(b) the double bell (see the Cor Anglais pipe in Plate III);

(c) the ''cap and slot'' (see Orchestral Oboe in Plate III), the cap being a metal lid soldered over the top of the tube all round, completely closing it, and the slot being cut immediately below the cap to enable outside air to get to the pipe. The area of the slot is variable by means of the usual ''tongue'' which is manipulated by the tuner and the voicer. The object of capping a reed tube is to muzzle the higher harmonics and obtain a smoother tone, which is not necessarily dull or lacking in harmonics below the point of attenuation. Opinion is sharply divided as to the merits or demerits of this process. I do not favour it myself except for special effects or in special circumstances.

In addition to the above there are other appendages which are more unusual though extremely useful under certain conditions. They are:

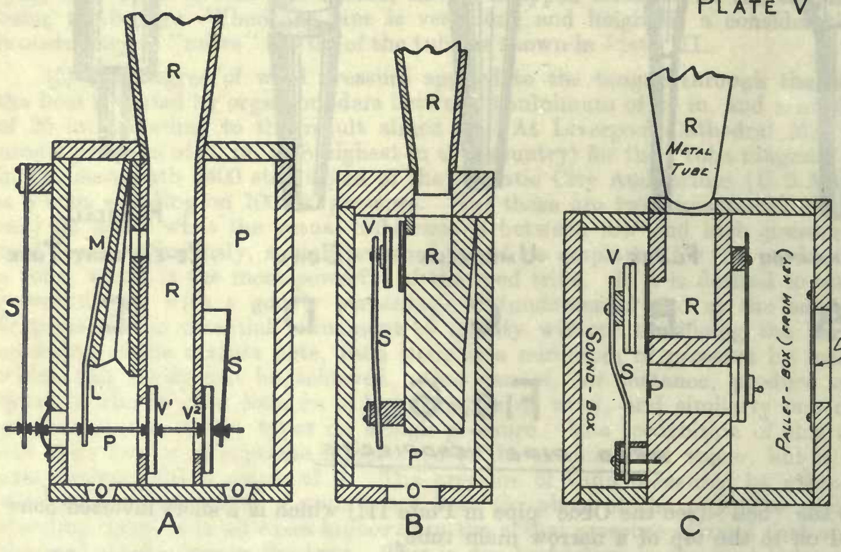
(d) the ''umbrella'' (devised by Vincent Willis), which acts as a shade over the top of the tube and stabilises the note, thus assisting the pipe to articulate promptly: (see Fig. 6C).

(e) the "compensator sleeve" which increases the fundamental harmonic and broadens the tone. This is inverted conical in shape if the resonator is inverted conical, and cylindrical if the resonator is cylindrical (see Fig. 6A).

(f) the "cowl" as introduced and used by myself in the organ in Stagsden Church. This has the effect of increasing the power and the **first three harmonics** of the note and also making the pipe speak more promptly (see Fig. 6D).

(g) the "flare" as introduced by the late Herbert Norman (see Fig. 6B). This is an extra large and long inverted cone soldered to the top of the tube with the object of greatly increasing the power output of the pipe for a large building without sacrificing the higher harmonics. Practically all the chorus reeds of the organ in the Colston Hall, Bristol, prior to its re-construction by Henry Willis in 1937, were so treated by Mr. Herbert Norman. Had they not been removed or replaced by fresh reeds in 1937 they would in any case have been completely destroyed with the rest of the organ in the fire of 1944. I am not aware that this device has been employed elsewhere, but the tonal effect so obtained is distinctly abnormal.

PLATE V



SS	Springs
M	Motor-pallet
R	Resonator
L	Lug
O	Orifice
PP	Pressure Chamber

DIAPHONES

The **Diaphone** belongs to the reed genus and so is mentioned here. The name was given to this type of producer by Robert Hope-Jones, who introduced it into his organs from 1893 onwards. The idea is supposed to have originated in the factory of Messrs. Blackett and Howden, of Newcastle, as far back as 1888, and several organ builders have related how a loosely hinged soundboard pallet has been known to set up a roaring sound which at first could not be traced to its origin. From this accidental performance of a vibrating pallet in a windchest must have sprung into being the idea of making a pipe function on this principle. Be this as it may, we find Hope-Jones making the most of this novelty and considerably reinforcing his pedal schemes with diaphonic tones. In place of the elastic lamina or tongue with which the organ reed pipe is fitted there is a disc-valve (or pallet) mounted on a steel spring. This is shown in Plate V. The early models had a pneumatic motor in place of the mounted disc-valve: the motor vibrated like a tremulant and set in oscillation the air column in the resonator. The introduction of the disc-valve resulted in a marked improvement in the tone, and Hope-Jones called this new type the "valvular reed." His version of it is shown in Plate VB. The motor type is shown at A; this latter was capable of great power on heavy pressure. At C is shown the latest development due to Mr. John H. Compton, who introduced (1) a detachable sound-box, (2) an adjusting set-screw at the bottom of the spring holding the disc-valve, (3) a non-resonant pallet-box. The vibrating disc-valve opens and closes the hole leading to the resonator without any graduation of the stroke, so that the pulses of air are abrupt and powerful. The tone, however, is not harsh and strident because the higher harmonics are considerably attenuated by the felted valve-head and consequently there is a complete absence of resonance frequencies in the vibrating mechanism. The lower band of harmonics are well favoured by the coupled system, and a "diaphonic violone" carrying far more fundamental than its flue pipe brother can be produced by the simple device of lengthening the steel spring and mounting on it a lighter valve-head. A heavy or loaded valve-head mounted on a short, thick spring ensures a smooth, foundational tone, and if the valve-hole is reduced in size, the volume of tone is likewise reduced. As in the case of reed tongues the valve has to be set at the optimum distance from the hole for prompt speech.

The resonator may be of wood or metal. Mr. Compton has employed every possible shape of tube to give differing results. A cylindrical tube of big diameter and half-length produces "tibia" tone, providing a very full and weighty pedal stop of 16 ft. pitch. A "diaphonic bourdon" can be made with tubes of half-length and a reduced valve-hole. If the tube is too long for the vibrator frequency, the note will fly up to a harmonic as in the case of the reed pipe. This was a common phenomenon with many of the earlier examples, which were also very irregular in the series of pipes, some being much louder than others. There was no means of adjustment provided, and no guarantee that once regulated the pipes would remain in that condition. Diaphonic pipes are not usually employed above tenor C owing to the heavily damped vibrator mechanism which deprives the higher-pitched notes of their necessary harmonic development.

The diaphonic pipe is best suited for the production of deep and penetrating notes in the pedal department, especially if these stops are enclosed in a swell box. It is well known that a pipe (or any kind of sound-producer) enclosed in a chamber suffers from a distinct loss of its fundamental harmonic. Since the diaphone possesses a strong, fundamental compared with a reed of the normal type, it would seem to provide a solution of the problem of enclosed pedal stops. It is nevertheless not in favour with many builders either in this country or in America (to say nothing of the Continental builders), and even the two largest organs in this country—at Liverpool Cathedral and the Royal Albert Hall—contain not a single example of it.

A word or two about the material of which organ pipes are made will not be out of place in this chapter. The metals employed in the construction of practically all metal pipes, flue and reed, are tin, lead and zinc. The tin used is not tin-plate, of course, but pure tin alloyed with ten per cent. lead. Pipes made of tin with not more than ten per cent. lead are very rarely to be found in the modern organ, though in the days of plenty and cheapness this material was often used even for the front pipes. The 32 ft. front pipes of the Royal Albert Hall organ are of tin, having been put there by Father Willis in 1870. But to-day no one would think of making pipes of tin if the same result can be achieved with an alloy of tin and lead in more or less equal parts. Alloys with 35 to 65 per cent. of tin cool with a surface showing spots of lead which present a characteristic appearance. This is known as "spotted metal." With a larger proportion of lead the spots do not show and the metal is then called "plain." Some pipe-makers add a percentage of "type" or antimony to the alloy to "stiffen the sheet," but this is quite unnecessary if the sheets are thick enough. Too large a percentage of antimony tends to make the metal brittle. I have seen the soldered joint of a diapason pipe so made come apart when cone-tuned; and apart from the brittle nature of the pipe it is impossible to get a satisfactory quality of tone from it. A little antimony mixed with tin and lead is not unsuitable for diapason pipes modelled on the early English pattern. Zinc is commonly selected for the larger pipes because it is cheaper and much lighter: it is much used for front pipes and for pedal 16 ft. reeds. It should be "hard-rolled" and not "baked" for the best results. Other metals can be used, of course, and have been used at various times by various builders on the Continent. Gold, silver, copper, brass, galvanised iron, steel—all have been tried. Experiments have proved conclusively that the quality of tone produced by an organ pipe is definitely influenced by the material of which it is made. It was commonly supposed at one time that the material made no difference, since (so it was alleged) the tone was solely determined by the geometric form of the air column. On two memorable occasions (not easily to be forgotten) I was attacked by critics who hugged this delusion because I stated that a pipe made of tin gave a different quality of tone from one made of plain metal. I could hear the difference. To-day, science has confirmed my opinion. What happens is that certain harmonics of the pipe-note are reinforced by the natural frequencies generated by the material itself. If those harmonics happen to be high up in the series, such as those above the seventh, it is not surprising that organ builders should boycott that particular metal. In fact, pewter gives the best results in that it reinforces the first seven harmonics, which explains its popularity. The attenuation of the higher harmonics is in this case due to the presence of lead. Wood is also a good material from this point of view, and has always been highly esteemed by organ builders. It should be well seasoned, of straight grain, and free from knots. Straight-grained, hard pine is as good as any kind for making pipes, while the caps and blocks are best made of smooth-grained wood or else of oak or mahogany.

Lastly, let me say a few words on the question of "formants." There is some difference of opinion on this subject: even among the learned expounders of physics it is possible to find those who seem, to judge from their writings, to be under a slight misapprehension as to the real nature of the formant. It is commonly supposed that the formant is the natural frequency of a vibrant material. Others identify the formant with the fixed resonant frequency of a cavity. These resonances possess one or more frequencies which remain unchanged in all circumstances; and if they happen to be associated with a sound-producing mechanism which generates the usual series of harmonics, then the resonance frequency or frequencies will add their contribution to the whole and reinforce one or more of the harmonics of the mechanism. Thus, if I sing the vowel "ah" on E flat above middle C, though my vocal cords are producing a note replete with harmonics with E flat as the fundamental, my mouth will be so shaped as to generate a cavity resonance whose frequency is 924 per second, and this particular frequency will impose itself on the third harmonic of my E flat note which is 922 frequencies at new Philharmonic pitch. And if I sing any other note on "ah," this resonance frequency of 924 will impose itself with unfailing persistency on my voice, thus ensuring that I make the "ah" sound. Now when we consider the functions of organ pipes we find that the above explanation of a formant inadequate; for we are dealing with whole bands of frequencies that have no relation to the fundamental and **do not necessarily reinforce any of the multiples of the fundamental.** It is a pure coincidence if any of the harmonics of the air column are reinforced by the formant frequencies: it might happen so in a few of the pipes of a stop and fail to do so with the remainder. Moreover, when a chord is played on a chorus of diapason pipes comprising unison, octave and superoctave ranks, the formant frequencies are multiplied to such an extent that they produce a "clash" of tones which is superimposed on the "clash" of harmonics generated in the combined air columns. These formant tones are not harmonics at all but a separate band of frequencies added to the harmonic content of the pipe or pipes. And this is not all. The formant is **not** just the natural resonant frequency of the material or the cavity associated with the construction of the pipe: these resonant frequencies generated by the vibrant material, be it tin, spotted or plain metal, zinc or wood, **modulate the frequencies generated by the air column and the vortex system** with the result that **a new band of frequencies is generated.** This is the real formant. It must be borne in mind that this new band of frequencies is not necessarily a strong component: it may be inaudible as such, yet may in conjunction with the main sound generated by the pipe alter the quality in a subtle manner. Formants vary in amplitude, but they never fail to influence the tone, and when several notes are sounded *en masse* the formant is a very real tone-painter. This explains the influence of the material selected for the various parts of a pipe. It explains why an aluminium tongue, or one made of soft brass, gives a different result to the note of a reed pipe from that given by a tongue of steel or of hard brass. It explains why zinc is a poor material for pipes less than eight feet in length, and why a reed pipe made of wood gives a duller note than one made of metal. It explains why a brass weight screwed on to the end of a reed tongue produces a less damping effect on the higher harmonics than a weight of felt or of lead and felt. It above all accounts for the differing results produced by different voicers and finishers, who unknowingly encourage or suppress a veritable legion of formants in their manipulation of the pipe-work under their control. In the days to come we shall discover even more about the formant; but we already know that it exercises a subtle influence on organ tone.

CHAPTER II

The Diapasons

HAVING taken a broad and general survey of the pipe-work of the King of Instruments, our next task is to examine more closely the four main categories of organ tone represented by the diapason, the flute, the string, and the reed. All organ tone is made up of one or other of these four types, but for the sake of a clear understanding of the tone-picture which the artist essays to create it is necessary to divide the four types above enumerated into the following tone-groups:—

1. Diapasons
2. Strings
3. Flutes
4. Octave and Mutation Work
5. Miniature versions of Nos. 1, 2, 3 and 4
6. Chorus Reeds
7. Imitative and special tones.

A chapter will be devoted to each of these groups with the exception of No. 5 (the miniatures). The miniature versions will be considered in relation to their own groups respectively, that is, the miniature diapason under section 1, the miniature flutes under section 3, and so on. Having described the various categories of tone, I shall embark on the important theme of tonal architecture, discussing the best way to use the various tones placed at our disposal.

The **Diapason** is put first on the list because it represents basic organ tone. It is a commonplace to state that what the "strings" are to the orchestra the diapasons are to the organ; but when this is said it is only half the truth. The strings are not characteristic of the orchestra: I mean, when I think of the orchestra as a medium for expressing beautiful sounds I do not necessarily think of string-tone. I may think of the wood wind or the brass just as readily as the strings. When we speak of "orchestral tone" we do not necessarily refer to any one category of tone. If the orchestra were to consist of strings only with no wood wind and no brass and no flutes, we should feel a distinct sense of loss: we should have a "string orchestra" or a string band, but we could not call it "the orchestra." A "brass band" is not the orchestra either. But an organ with diapasons only *is* an organ. No one, with any knowledge of or respect for classic tradition, can deny the title of "organ" or "king of instruments" to a wind instrument giving the characteristic quality of the diapason even if all the other categories of tone are absent. Objections may be raised on the ground of monotony: that is a matter of personal taste. But fundamentally, characteristically, actually, the Organ is there. The diapason is more than the tonal foundation of the Organ, it is the Organ as far as its tone is concerned. If I take a diapason pipe and blow through it I am sounding "organ tone": if I take a violin and draw a bow across the G string I am not sounding "orchestral tone," but string tone.

What exactly is diapason tone? How can we determine its essential character? We can take a diapason pipe and so manipulate its parts as to modify its tone up to a point without depriving it of its basic quality. But what precisely is that point? The pipe can be made more "stringy" or more "fluty" in tone until the degree of "stringiness" or the degree of "flutiness" exceeds the limit and the tone is no longer that of a diapason. **When have we crossed the borderline on either side of the tonal spectrum?**

There are two ways of answering this question. One is to make the ear the arbiter, the other is to take an analysis of the harmonic content of the pipe. There are objections to the aural method. The ear is undependable: my ear is not my neighbour's, and my judgment may differ from his. And I may be biassed in favour of a certain type of diapason tone and pass an unfair verdict. In any case, the dictum of a musical critic who depends on his aural faculty for deciding such a question must always be suspect. He may be wrong, and the question remains unanswered. Or he may be right, but how is he to prove that he is? So we are brought up against the necessity of employing a more satisfactory instrument from which we can draw a definite conclusion. The harmonic analyser provides us with such an instrument. We will, therefore, examine the harmonic content of four different organ pipes sounding middle C note and see what their respective analyses can tell us. In Fig. 7 I have drawn a line through the ends of the ordinates of each of the four pipes referred to so as to indicate the comparative configuration-curves. Curve 1 (thick line) is that of the viole d'orchestre giving a keen tone rich in harmonics: curve 2 (double line) is that of the diapason of normal quality: curve 3 (thin line) is that of the geigen giving a diapason tone of somewhat keener and richer quality than normal; and curve 4 (dotted line) is that of the open metal flute with high cut up mouth giving a full, dull tone. Thus, curves 1 and 4 represent the two extremes of tone, while curves 2 and 3 fall in the middle. A close scrutiny of each curve reveals the following points:—

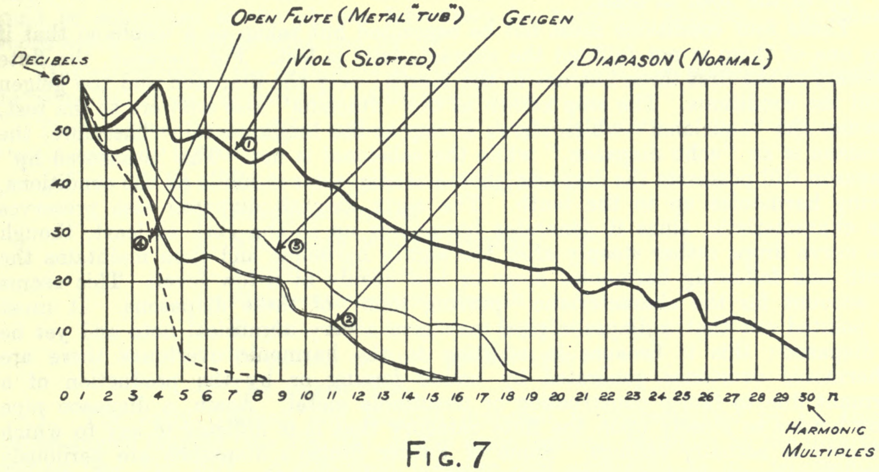


Fig. 7

Harmonic Analysis of Four Different Flue Pipes (Middle C note)

(1) Every harmonic, both odd and even, is represented along the whole distance of the curve:

(2) all the curves except No. 1 show the fundamental harmonic as the most pronounced:

(3) the diapason and the geigen exhibit a droop from the third to the fifth harmonic, which is not seen in the curve of the viol:

(4) the flute does not show any harmonics above the eighth:

(5) the viol curve rises precipitately from the second to the fourth harmonic and then drops as precipitately to the fifth, from which, like the other three, it shows a gradual decrement:

(6) the lengths of the curves vary considerably when we compare Nos. 1 and 4 with Nos. 2 and 3:

(7) Nos. 2 and 3 have a strong family likeness, which is more apparent if the graph is shortened with the ordinates placed closer together so as to smooth out the irregularities.

From the foregoing observations we may deduce these four essential conditions that determine true diapason tone:—

(1) The fundamental harmonic must be the strongest:

(2) both odd and even harmonics must be present in the series:

(3) there must be a drop from the third to the fifth harmonic:

(4) harmonics must be developed between the 10th and the 18th, and up to the 10th at least.

These four conditions must not be separated but taken as a whole so that if any one of them is not fulfilled the characteristic is lost. For instance, the flute answers to the first three but not to the fourth: only the diapason and the geigen fulfil the conditions. The stop known as the "dulciana" also answers to the test, but not the "salicional" which shows a drop at the fundamental. Therefore, the dulciana is an "echo diapason," while the salicional is not. The "leathered lip" diapason still possesses the diapason characteristic, since it fulfils all the conditions, giving harmonics up to the tenth. The early English diapason also preserves the characteristic, since it generates harmonics up to the 12th at least, though the curve drops rather steeply after the eighth harmonic and then maintains the ninth and following harmonics more or less evenly at a low level. This seems to account for the characteristic "purring tone" of these diapasons. It must be pointed out that a diapason pipe may give a very unmusical note and yet be a diapason: this is because in addition to the harmonic overtones there are inharmonic overtones generated by undue forcing or by the production of a formant due to faulty construction or unsuitable metal. Again, a diapason pipe may border so closely upon the flute category that it is difficult to say to which category it actually belongs. Some of Father Smith's diapasons are perilously near the danger-point. I have no harmonic analysis of these pipes, so that I am not in a position to make a definite statement, but I should be inclined to give them the benefit of the doubt. On the other hand, there are examples of slotted diapasons of relatively small scale which encroach on the string category, since their first harmonic is not as strong as the second, third and fourth. With a larger scale of pipe, or possibly a wider mouth, they would lapse into the diapason class, since the slot does not in itself destroy the characteristic, even though it may be detrimental to the quality.

According to Dayton C. Miller the "ideal tone" would conceivably be produced from a sound-generator giving a strong fundamental accompanied by a complete series of, say, twenty harmonics of successively diminishing intensity. There is no known musical tone-producer that can do this, but the nearest to this ideal is attained by three sound-producers only in the world of tone: (1) the diapason, more especially from tenor C to middle C, (2) the French horn in some of its lower notes, and (3) the human voice in its middle range when properly produced. I am careful to avoid specifying too exactly the various zones in which each of these three instruments is able to produce the quality of tone under consideration, nor is it necessary for me to make the attempt. I am mainly concerned to show that the organ diapason ranks very high indeed in the hierarchy of tonal values, and that the organ as a musical instrument does depend very seriously on the artistic manipulation and treatment of its diapasons.

Meanwhile, the question of what constitutes diapason tone and what does not will doubtless be settled by ear, since organ builders in general cannot be expected to submit specimens of their pipework to a harmonic analyst for a report on the tonal characteristic of this or that stop. In spite of the notorious tendency of the human ear to adapt itself to circumstances and to accept that which is purely subjective and imagined, those who are in constant touch with organ pipes and have had the incalculable benefit of a ripe experience in the art of voicing and finishing can as a general rule be relied upon to exercise a very nice discrimination in tonal matters and are not dependent on any confirmation by scientific analysis. In the case of a dispute, arising from any cause, between builder and client, or a challenge issued by a controversialist(!), the pipe or pipes in question could be submitted to the physics laboratory for harmonic analysis. The chart would settle the dispute once and for all.

Having discussed the basic tone of the diapason, I will now proceed to describe the principal types (or variants) of diapason pipe.

There appear to be eight main types of diapason known to us to-day, which I enumerate as follows:—

1. Early German and English:
2. Baroque German:
3. Nineteenth century German:
4. Victorian English:
5. Nineteenth century French:
6. English and American foundation type:
7. Twentieth century special type:
8. The geigen type.

1. The early German and English diapason is characterised by its thin, obtuse-angled languid (see Fig. 3A), and in some German examples by the inverted languid (see Fig. 3D). A low wind pressure, not exceeding 2½ in., is essential to the production of this type, in which the harmonics are not developed beyond the tenth or twelfth. The mouth is cut up low, that is, not more than a fifth of the inside diameter of the pipe; and as a rule the mouth is fairly wide, not less than a fourth of the inside circumference of the pipe. The nicking is quite shallow and not so close as in modern examples: the inverted languid is not nicked at all, nor are some of the normal languids. The flue is kept quite narrow and the upper lip in a vertical line, neither concave nor convex in relation to the lower lip. This latter lip is "straight-flatted" instead of being "dubbed" (i.e. curved in towards the edge of the languid as in the modern pipe—see Fig. 3C). The scaling varies between the limits of 1⅞ in. and 1½ in. at the 2 ft. pipe (middle C), but in many cases the diameter of the tenor C pipe halved at the octave above, so that the scale became relatively smaller in the upper portion of the register. The

result of such relative scaling is to make the upper notes rather weak, so that when a chord is played the top note is almost engulfed by the notes sounding below it. Hence the treble register was reinforced by many ranks of mixtures in order to redress the balance. Not that mixtures (about which I shall have more to say in Chapter V) were introduced for this reason only—far from it; but they were found indispensable for the purpose of equalising the power output of the tonal scheme, among other reasons. The metal employed for the construction of the earlier types of diapason was of poor quality according to later standards: there was a goodly proportion of lead and very little tin in the alloy. Actually, this high percentage of lead is essential to the peculiar quality of the type, since the object of the voicer was (and is, if the type is to be reproduced in the modern organ) to keep down the higher harmonics and produce a sombre effect, reposeful and mellifluous to the ear. I believe it was the late Dr. J. W. Hinton who once remarked to the late John Matthews (of Guernsey), "these old diapasons with their old-type languids used to **sing**: the modern diapason with its acute-bevelled languid **whines.**" Dr. Hinton was a connoisseur of tone and possessed a highly critical ear, as I discovered when I discussed organ tone with him at a never-to-be-forgotten meeting. He was a great advocate of "unforced, natural" quality from organ pipes, and for this reason much admired the work of the old builders. I remember visiting the organ by Griffin the Barber in St. George's Church, Southall (Middlesex) and marvelling at the unearthly beauty of the 8 ft. diapason on the great organ. This stop dates back to 1707, and speaks on 2½ in. pressure. I carefully examined the pipes and reproduced them as closely as possible in a small organ I had rebuilt in St. Peter's Mission Church at Uxbridge (Middlesex). Many organ enthusiasts came to try this stop, which was (as far as I am aware) the first example of a reproduction of the early English diapason in this country. I can well remember the late Leonard K. Boseley sitting at the organ and improvising on this diapason with a seraphic expression on his face and exclaiming "Nothing like it, my boy, nothing." This little instrument was sold later, and the diapason is now functioning in the chapel organ of the Bishop's Hostel, Lincoln. Its scale is 3 in. at tenor C (4 ft.), 1¾ in. at middle C (2 ft.), and 1-1/16 in. at treble C (1 ft.): the mouth width is a fourth of the circumference and the cut up is a bare two-sevenths of the width.

2. The next type of diapason we must consider is that which was produced by the German builders of the late seventeenth and early eighteenth centuries. There were Casparini, Arp Schnitger, Scheibe, and the Silbermanns—these great artists developed organ building to a very high pitch of tonal perfection within the limits imposed on them by the crude mechanism of the period. Indeed, it is highly probable that they would never have created such tone-pictures if they had not been restricted by considerations of mechanical control. Be this as it may, each of them worked out a definite scheme of tonal architecture which in its own class is generally regarded as beyond criticism. I am only concerned in this chapter with the unison diapason, so that an examination of the complete tonal scheme of this or that builder or period of organ building must be left to a later chapter. I must also make it clear that although I am classifying the diapasons of these "baroque" builders in this particular section, each of them produced a somewhat different version. It was, however, the way in which the diapason *chorus* was treated by each that constitutes the real and basic difference between them. The quality of these diapasons was in all cases "smooth" and mellow, even though they possessed a certain subtle degree of virility lacking from the examples of previous centuries.

Schnitger, employing metal containing a large proportion of lead (in the ratio of 10 to 3 of tin), so as to avoid a sharp quality of tone, made the middle octave of his diapasons much fatter than the lower and upper. Here is a typical example: CC (8 ft.) 5⅜ in., T.C. (4 ft.) 3¼ in., middle C (2 ft.) 2-7/16(!), treble C (1 ft.) 1½ in. The outside pipes (in the case) were of ninety-five per cent. tin, but the inside pipes were of "metal" as above stated. Note the extraordinary increase of scaling between tenor C and middle C, and the corresponding decrease between middle C and treble C; for normally middle C would measure 1⅞ in. and not 2-7/16 in. The octave rank would not, however, be so scaled, but would follow the more normal ratio of "halving on the seventeenth" (see Chapter X for an explanation of relative scaling), and the 2 ft. C would measure 1⅞ in. at the most. The mouth was a fourth of the circumference in width and cut up at most a fourth of the width on a wind pressure of 3 in. to 3½ in.

The diapason work of Casparini was more brilliant than Schnitger's though by no means stringy. He was the great pioneer of modern diapason tone and undoubtedly influenced the German school of the nineteenth century to which Schulze belongs. He adopted comparatively large scaling with wide mouths and a low cut up, while his octave ranks were all of the same scale as the unison rank. His metal never contained less than fifty per cent. of tin. The nearest to his type of diapason that I can refer to is the (now) No. 2 diapason on the great manual of the Schulze organ in the Parish Church of Doncaster.

The influence of Casparini on Scheibe (Bach's organ builder) and the Silbermanns was marked, but the Silbermanns, and more particularly Gottfried (the younger brother), introduced a smoother quality in their diapasons. This was achieved by employing an extra thick languid occupying as much as a third of the height of the mouth, and a flat bevel. The upper lip was also slightly pulled outward so as to quicken the speech of the pipe. The relative scaling was different from either Schnitger's or Casparini's: the half diameter fell on the fifteenth note. Thus, if the tenor C pipe measured 3⅜ in., the middle C pipe would be 1-15/16 in., and the C above would be 1-1/16 in. The CC pipe would be as much as 6½ in. Compare with this scaling that of the Schulze Doncaster diapason above mentioned: CC, 6½ in., T.C, 3½ in., middle C, 1¾ in., treble C, 1¼ in. The middle C pipe affords the clue to the general design in both cases. Normally it should be quite 2 in. Silbermann used at least ninety per cent. tin, and often 99.5 per cent. The quality of his diapasons with wide mouths cut up quite low and voiced to give a rather fluty tone is said to be indescribable. One American writer has stated that the nearest equivalent would be a "concert flute on the solo organ," but this tells us either too little or too much. There is obviously the "bloom" of the flute combined with the vivacity of the diapason, and the total effect could only be appreciated when (a) the unison diapason was played in chords and (b) it was combined with the rest of the diapason chorus which was given more brilliance than the unison rank. The secret of Silbermann's wonderful ensemble lay in his treatment of the octave ranks and mutations, and the unison rank provided a substratum of pure diapason tone which fitted snugly in its place. Low pressure, no ears, and even no nicking were quite common features of Silbermann's work. But it was Casparini (and his admirer Scheibe) who paved the way for the next type of diapason.

3. The nineteenth century German diapason is associated with the name of Schulze, though Walcker (of Ludwigsburg) and other German builders also produced similar diapasons to those of Schulze's earlier examples. The "Schulze

diapason,'' of which I have made a special study, is probably the most misunderstood and most misrepresented of all organ tones. The German builders of Edmund Schulze's day were jealous of the fame he had acquired in this country and condemned his work (or else damned it with faint praise). Nor is his work thought much of in Germany to-day to judge from contemporary criticism. He is credited by certain writers on organ matters with producing harsh and stringy diapasons which are not suited to modern ears and become very wearisome after a few minutes' listening. ''One must guard against the string quality of a geigen or a Schulze'' is a sentence I quote from an American journal. Yet no one can honestly attribute ''harshness'' or ''stringiness'' to the Doncaster diapason work, which resembles that of Silbermann in many important respects. The Silbermann diapasons (unison rank) were more fluty, but it would be extremely difficult to detect what the difference really is at a distance of say a hundred feet from the pipes. The feature they possess in common is mellowness: there is a complete absence of ''edginess.'' But Edmund Schulze during his stay in this country developed his diapasons and introduced a type of quality all his own. This new type has rightly been called the ''Anglo-German,'' since it is peculiar to Edmund Schulze. First, the Casparini type was developed into the J. F. Schulze type with wide mouths cut up low, on a pressure of 3¼ in. to 3⅝ in. and standing on magnificent soundboards with the wind supplied direct to the pipe *via* a large groove-chamber: then Edmund Schulze further developed his father's diapasons by increasing the size of the foot-holes and obtaining the full tone from each pipe. He also increased the width of the mouth from four-fifteenths to two-sevenths of the circumference so as to meet the extra pressure from the pallet. The upper lip was well pressed in and the flue made slightly wider, while the edge of the upper lip was burnished in front only (not at the back) in order to eliminate the higher harmonics above the 16th (or at least to render them innocuous). The nicking was very fine and close. The Casparini scale ratio of half on the seventeenth note* was scrupulously observed. The type of pipe used is illustrated in Fig. 3B. The result was a pure diapason quality, completely innocent of harshness or (which is a thousand times more to the point) hardness. Yet there was introduced a most extraordinary richness of texture in the harmonic content, akin to the mellow quality of the Stradivarius violin without a particle of its stringiness. The whole of the harmonic content above the fourth partial was in some magic way converted into sheer quality, a quality which no one is able to reproduce. If this particular quality has been reproduced, I have not heard it. I certainly have not reproduced it in my own work, although I made the attempt in a set of diapasons, 16 ft., 8 ft. and 4 ft., which I sent to the First Methodist Church at Hamilton, Ohio, in 1926. These diapasons were, I believe, the nearest to the Schulze examples at St. Bartholomew's, Armley (Leeds) that a later voicer can accomplish, since the pipes were copied most meticulously; but they were not placed on Schulze soundboards, so that they could not possibly be the same in quality of tone. This is not to say that they were ineffective—far from it judging from reports received; but it is hardly correct to say that the Armley diapasons were heard for the first time in America in 1926. If one wishes to hear the real article one must pay a visit to Armley itself or to Tyne Dock (St. Mary's Church): I do not know of any other examples of the Anglo-German Schulze diapason voiced by Edmund Schulze (except possibly at Christ Church, Doncaster, where Schulze erected a small instrument). The famous Hindley organ (St. Peter's Church) does not provide us with diapasons or upper work by Schulze as left by him. I heard this organ in 1899 and on that occasion the pipework was untouched: I then considered it the finest example of Schulze's voicing in this country, easily transcending his work at Armley, Charterhouse and Tyne Dock, though not comparable in actual quality of tone with Doncaster which represents an entirely different ideal. The diapasons on the great manual were as smooth as any Father Smith or Silbermann example, but to this wonderful mellowness (a feature that impressed me as outstanding) was added an even more remarkable "Stradivarius G string flavour," a very subtle colouring of deep purple velvetiness **which was entirely new to me.** I stress this point, because it does not seem to be appreciated to-day **what Schulze was doing.** The late Henry S. Vincent and Leonard K. Boseley both testified to the same impression that struck me, namely that these particular examples were absolutely unique in quality, possessing a velvety richness combined with extraordinary depth of tone. In 1908 I again visited the organ and found that Schulze's tracker-pneumatic action had been recently replaced by tubular-pneumatic action, doubtless a much-needed improvement. On placing my hands on the diapasons I at once noticed a change. The old sparkling **richness** had gone: the smoothness was still there, but not that amazing "Stradivarius" timbre, not the deep purple tinge of colouring. The octave ranks and the mixtures stood out more prominently. Listening to the diapasons and to the full great fluework at a distance of fifty feet from the console I was struck by the change that had occurred in the blending of the various ranks. My impressions were confirmed at a later visit—my third—in 1930, when I was accompanied by the late Rev. A. T. Hollis, a great organ enthusiast, who had never heard the organ before. He was frankly disappointed. He thought the unison diapasons excellent, and remarked: "You have done examples quite as good as these!" When the tubular-pneumatic action was applied in 1907 the wind pressure on the great manual was increased by an additional ⅜ in., and the metal pipes were revoiced, in some cases the foot-holes were reduced while in others the mouths were slightly increased in cut up. The builder who carried out the work was present at my second visit, and when I detected the change of tone I asked him point-blank what had happened. He thereupon told me. He had cut up the mouths of the great diapasons slightly* from tenor C up, and had "knocked up" the foot-holes of the other metal flue pipes where necessary, leaving the smaller pipes untouched. This builder was in my opinion an artist and produced some really fine work on his own lines which I greatly admire; but since he was compelled to adapt Schulze's pipes to the extra pressure, we may not rank the Hindley diapasons as **actual** examples of Schulze's artistry. I think the reeds were improved by the increased pressure, and the wonderful wood string pipes did not seem to have suffered; but the diapason work of this instrument, whatever may be thought of it, is not Schulze's as he intended it to be. I have dilated—perhaps at undue length in this section—on the subject of the Hindley organ; but I have thought it necessary to state the case for Schulze and to protect him from unfair criticism. There are many organ critics who do not hesitate to make statements about this artist who have never even heard his real work. The time will inevitably come when his art-creations at Doncaster and Armley will be ranked amongst the world's greatest treasures, if they are preserved as hitherto. The Edmund Schulze diapason stands in a class by itself: it represents the peak to which the voicing and treatment of the diapason was lifted in the sixties. The nineteenth century German diapason was **not** brought to its maturity in Germany but in England. There are no similar examples in Germany or any other country. Three English organs alone possess this diapason tone. There were several other examples, but they have all been destroyed or modified.

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* According to Robertson, Schulze halved his diapason scaling on the sixteenth pipe. I have found that this is not so; but on the seventeenth as a general rule.

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* I would point out that to increase the height of a two-sevenths mouth diapason a fraction even beyond a quarter of its width is extremely risky.

It will be asked: What actually constitutes the peculiarity of the Schulze matured diapason? No harmonic analysis of the pipes has been made. If we possessed this harmonic chart we should not have derived more than a particle of the information we require for determining the ingredients that collectively constitute the finished product. One thing is certain. If we take a Schulze diapason pipe from its soundboard and place it on another of even slightly different design or measurement, it ceases to be a Schulze diapason. That this is even now a little recognised fact shows to what extent misapprehension about the whole subject of Schulze tone still persists. It was in1899 that Mr. L. K. Boseley, after hearing the famous instrument at Tyne Dock, challenged Mr. Henry Vincent (in whose care the instrument was at the time) to reproduce the No. 1 diapason in his (Mr. Boseley's) organ at New College Chapel, Hampstead, London. Mr. Vincent accepted the challenge and proceeded to make an exact replica of the Schulze pipes. In order to make doubly sure of the success of his attempt at reproduction he replaced certain pipes on the Schulze soundboard by his own pipes and manipulated them so as to make them indistinguishable from the original. I was not present at this experiment, but Mr. (now Bishop) James Wedgwood was there and testified to the success of Mr. Vincent's effort. Mr. Vincent was not, however, content with reproducing the pipes: he also reproduced the soundboard on which the original stop stands. The new diapason was duly installed in the organ at New College, Chapel, Hampstead, and very fine it sounded. The only difference between the original and the copy was in the metal employed: Schulze's pipes are of thick spotted metal, while the Vincent pipes were of "unplaned metal." Further, the stop did not include the lowest octave of pipes from CC to BB, the old Walker front being utilised for the bass. It must also be realised that the reproduced stop formed no integral part of the tonal scheme of the New College Chapel organ, the other stops being much smaller in tone and in consequence smothered by the big voice of the new diapason. The latter was therefore only available for accompanying a large body of singers or for providing a powerful solo voice with full swell accompaniment. These pipes are now standing on a different soundboard (with no grooves between pipe-foot and pallet below) in the Roman Catholic Church at Slough, where the effect they produce is entirely different, proving how profound an influence the soundboard exercises on the tonal result. The Tyne Dock example was considered the culminating product of a genius by those who heard it for the first time in the sixties and seventies. The late William Thynne was quite lyrical in his eulogy of it: so was the late T. C. Lewis, who copied it in several of his larger instruments, notably at St. Alban's, Teddington, St. Saviour's Cathedral, Southwark, and St. Peter's, Eaton Square. Mr. Vincent made other copies, notably at Keble College Chapel, Oxford, and Messrs. Abbott and Smith reproduced the pipes in the organ at the Roman Catholic Church, Cambridge. Yet all these examples are different in tonal character and effect! None really reproduce the Schulze original. There was, prior to its removal from its Schulze soundboard and its revoicing on a higher pressure with an increased cut up of its mouth, an even finer example of big diapason tone than that at Tyne Dock in the organ in Leeds Parish Church. Dr. Audsley told me he regarded this as the "last word" in diapason tone and voicing, and I believe T. C. Lewis thought likewise. I heard it myself in 1901 and never have I heard the like since till . . . , but first let us see what gave this stop its unique character. Its mouth was between a fourth and a two-sevenths width, namely four-fifteenths of the pipe's circumference, and was cut up four-nineteenths of the pipe's inside diameter. The scale was the same as that of Tyne Dock, but the pressure was half an inch higher, namely 3¾ in. The tone was fuller and more foundational than that of the Tyne Dock example (which to my ears has too high a harmonic development in its middle register). The soundboard was specially constructed to supply the requisite head of wind to each pipe with the minimum of discrepancy between pallet and flue pressures. As above stated, this stop is no longer the big No. 1 great organ diapason that Schulze created, but as close a copy as human ingenuity can achieve is fortunately in existence to-day in the organ at St. George's, Kidderminster, so that it can safely be stated that this latter example represents a unique diapason effect in so far as the original Leeds example was unique. Three of its pipes are to be seen in Mr. H. A. Frampton's photograph.

Now the big tone of the Tyne Dock and Leeds diapasons aroused considerable attention at the time of their introduction; this was only natural. But from the normal and architectural viewpoint they were not the equal of those smaller diapasons at Doncaster and Hindley or even the somewhat larger one on the great manual at Armley. Let us see what the scales of these diapasons are as compared with that of Tyne Dock or Leeds. The following list reveals the comparison:—

	CC	T.C	mid. C
Tyne Dock and Leeds No. 1 Diapason:	6¼ in.	3¾ in.	2¼ in.
St. Bartholomew's, Armley, No. 1:	(wood bass)	3⅜ in.	2⅛ in.
St. Peter's, Hindley, No. 1:	(wood bass)	3¼ in.	2 in.
St. George's, Doncaster, No. 1:	6½ in.	3½ in.	1¾ in.(!)

The term No. 1 applies to the original organ in each case and not to the organ as it now stands except in the case of Armley and Hindley. All these stops have two-sevenths mouths, cut up a fifth of the diameter, except the Leeds example. The second (No. 2) diapason at Hindley measures 2⅞ in. at 4 ft. C and 1⅝ in. at 2 ft. C, while the swell diapason is 3⅛ in. at 4 ft. C and 1⅞ in. at 2 ft. C. The second diapason at Doncaster, originally labelled "Octave," is 3⅛ in. at 4 ft. C and 1⅞ in. at 2 ft. C. The scale of the double diapason, 16 ft. is the same from 2 ft. upwards, the 4 ft. pipe measuring 3¼ in. as compared with 3⅛ in. Obviously, the "Octave" is the octave of the double. A glance at these scales shows that Schulze did not invariably follow his rule of half on the seventeenth note. They also show that he was induced on occasion to provide a diapason of extra power presumably to support the singing of a large mass of people. But when we speak of Schulze diapason tone we should avoid picking out the exceptional examples of his work and study more closely the more normal types together with their families of upper work. Such a word as "brilliance" can be most misleading in reference to organ tone: it has been applied to the choruses of Schnitger, Silbermann and Schulze alike; yet we know how radically these three types of ensemble differ from each other. The one epithet that can and ought to be applied to the tonal quality of Schulze's organs, viewed as a whole, is **rich.** This word accurately describes the tone of his diapasons: rich in harmonics without the introduction of unwanted harmonics, rich in formant frequencies, rich in differential frequencies, rich in blending capacity, rich in carrying capacity, rich in single notes as in chords. Perhaps the closest imitation of a Schulze diapason of normal power is to be found in the Parish Church at Micheldean (Glos.), which is a copy of that at Armley and stands on a soundboard which I designed for it. This stop was made and voiced by Messrs. Kingsgate, Davidson and Co. under my supervision. I know of no other quite like it: certainly not any other examples of my own work; but I am not convinced in my own mind that it is a true copy of Schulze*. How subtle is the quality of this type! It has eluded me all my life like some will o' the wisp or Maeterlinck's Blue Bird. It was after the production of the Micheldean stop that I wrote my book, "Modern Studies in Organ Tone," in which I pleaded for the "ideal soundboard" for diapasons as the only means of reproducing the true Schulze characteristic. Yet even with the ideal soundboard at hand it is fatally easy to miss the desired result, since there are a hundred and one different ways of manipulating the pipes as well as of making them. The formant is as elusive as it is essential, and I do not know how it is obtained. No wonder Edmund Schulze, on hearing that a certain firm of English builders were boasting that they were in possession of his scales and would be able to produce his results, exclaimed, "Ach! they may have all my scales, but they will not know how to use them." How true this is! Not to-day do we really quite know "how to use them," and if we did, how many of us would be content with the result? An organ builder must have **ears to hear with** as well as technical ability. Schulze had both these assets. Hence his greatness.

4. We come now to the Victorian English diapason. This is associated with the name of William Hill. Hundreds of examples could be heard in the cathedrals, parish churches, chapels and concert halls of this country when I was a boy. There are still some that have survived, but most of them have been either revoiced or removed in the process of reconstruction. They were quite beautiful in their way, singing naturally on a pressure not exceeding 3 in.—the rule laid down by William Hill and jealously guarded by his successors. In a lecture given by the late Dr. Arthur G. Hill to the Royal College of Organists shortly after the building of the then largest organ in the world (Sydney Town Hall) the statement was made that pure organ tone could not be obtained from organ flue pipes from a wind pressure exceeding three inches. Exactly what was meant by "pure organ tone" is not clear: it was a phrase much used by both George Ashdown Audsley and Thomas C. Lewis. Presumably it refers to the natural, unforced quality of lightly winded flue pipes giving a moderate proportion of nature's harmonic series along with a pronounced fundamental. If so, there is much to be said for the opinion expressed by these three lovers of the King of Instruments. The late Dr. Edward J. Hopkins would have cordially subscribed to this sentiment, and also Dr. J. W. Hinton. The Hill diapason, to be described in this section, undoubtedly answered to this test of purity. The scaling was never overdone even for the largest buildings (such as York Minster, Beverley Minster, Westminster Abbey, King's College Chapel, Cambridge, and Lichfield Cathedral). The mouth was usually a fourth of the circumference in width and cut up a bare fourth of the diameter (actually about three-elevenths): the foot-holes were on the small side, the flue narrow, the upper lip quite sharp-edged, and the nicking shallow and close. The chief difference between the Hill diapason and the diapasons of the earlier builders lay in the languid: Hill's languids were at least thirty per cent. thicker and had a moderately acute bevel as shown in Fig. 3B; but the flatting of the lower lip was only slightly curved toward the languid. The pressure was, of course, somewhat higher, and accounts for some of the difference in treatment; for in order to retain the low cut up of mouth and preserve the unforced

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* I would claim, however, that my great No. 1 diapason at St. George's, Kidderminster, is to all intents and purposes a replica of the Leeds Schulze diapason.

quality of the old builders it was necessary to keep the foot-holes small—in other words to blow the pipe so that the full tone was not obtained from it. In this particular we see the fundamental difference between the Hill and the German method of voicing. The underblowing of a flue pipe may be a fruitful source of distortion in that the vortex system is loosely coupled to the columnar system and thus a lack of integration in the resulting tone may result. This was a fault in the Hill stop in question, and it was very noticeable in a non-resonant building; its presence accounts for the "revoicing" of many of these diapasons by subsequent builders. I must plead guilty myself to having revoiced two Hill diapasons in 1904, namely the original Nos. 1 and 2 in the organ of Keble College Chapel, Oxford. The beautiful swell diapason I refused to touch: one must not attempt to paint the lily. But the great No. 2 responded to the treatment I gave it with alacrity. This was a real success as it chanced: the late William Arthur Barr (the son of Robert Barr, the author and journalist), who was at Oxford with me, was never able to get the tone of this diapason out of his head. His last letter to me, written from the trenches in Flanders in 1916 shortly before his tragic death, contained these words: "There is still only the one diapason for me—that lovely No. 3 at Keble—I would have a chorus built up of this tone and only this tone: I would wish for nothing more, just that." All that I had done to the pipes was to burnish the posterior edge of the upper lip from tenor C to top note and to enlarge the foot-holes, adjusting lips and languid. The thickening of the upper lip reduces the harmonic development of the pipe, though it is the higher harmonics above the fifteenth partial that are mainly affected: the result is a **softer** quality. In order to reintroduce the higher harmonics it is necessary to increase the pressure of wind at the foot, and this operation also restores the original power of the pipe. Thus, the tone is the same in strength as before, but its quality is altered to one of rich softness. It is a tricky operation, moreover, since it is easy to overdo the process of burnishing and produce too dull a tone: it is supremely important that each and every pipe in the series should be given the same treatment, neither too much of the burnishing nor too little. It was only a few months later that Mr. Henry Vincent, at my suggestion, added a new No. 1 diapason in the shape of a "Tyne Dock replica" on a new and separate soundboard (referred to in the previous section). The two diapasons originally put in by Hill are now Nos. 2 and 3. I have cited the instance of Keble No. 3 in order to show that the Hill diapason of this period, beautiful as it was, was not entirely free from certain deficiencies. It was underblown in relation to its scaling, a fault which was extended to the octave ranks as well: the tone was not forced, the fault lay in the opposite direction; and the diapason chorus suffered accordingly. There were exceptions, however. At St. George's, Ramsgate, and Eton College Chapel—to mention two examples—the diapason work was not underblown; nor was it at Peterborough Cathedral. This good old firm **could** turn out really splendid diapasons, but generally speaking the tendency was to supply insufficient pressure of wind at the mouths of the pipes.

5. In France Aristide Cavaillé-Coll was producing a very different kind of diapason. The French ideal is not the same as ours: "brilliance and edge" are of greater importance than "foundation and fullness." The same tonal conception is observable in the French pianos: their boys' voices are "reedy" compared with the English: their radio transmissions are more high-pitched. It is, therefore, not surprising that their diapasons should be thinner and more metallic (to our ears) than those of Germany, Britain and America. The thinning of the tone was accomplished by the process of slotting the pipes, and also keeping the

scales down to a moderate dimension. The characteristic was further ensured by the use of a very high percentage of tin in the pipe metal, thus encouraging a high-pitched formant. But the principal cause of reediness was the narrow slot. Father Willis at one period of his career favoured this slotting process and applied it to all his diapasons. The result was a hard, horny quality: although it must be admitted that his diapasons when so treated sounded very effective in a resonant building and possessed no mean architectural capacity. Furthermore, they did not interfere with the full reed ensemble for which Willis was justly famous. But the earlier diapasons of this great builder were much finer and far more beautiful as such: they were unslotted, and produced a lovely, velvety, round tone, the very antithesis of the slotted type. In my opinion, slotting is a pernicious practice to be avoided as far as possible. Even a wide slot right at the top of the pipe for tuning purposes only adversely affects the quality of a pipe. Cavaillé-Coll himself explained why he adopted the process: it was to prevent the journeyman tuner from "pinching the pipes" ("*ces entailles les préservent de la détestable practique des mauvais accordeurs qui pincent les tuyeaux*"). Quite so, but the modern tuning slide solves the problem far better.

6. The influence of Edmund Schulze on English organ building was very marked and led to the adoption of more powerful diapasons. Furthermore, the employment of heavy wind pressures for the voicing of chorus reeds, especially by the firm of Henry Willis, made it possible for voicers to increase the output of their flue-work so as to give it a better chance of "standing up to the modern chorus reed." Imitation of Schulze's Tyne Dock and Leeds diapasons resulted in the production of harsh and strident tones of a non-blending character, and it was found that heavy pressures did not suit the Schulze wide, low mouth. If the foot-holes were reduced to prevent overblowing or unstable speech, the tone would lose its richness and assume a disappointing mediocrity; while the cutting up of the mouth as an alternative to bore-reduction would deprive the pipe of its essential harmonics, producing a hard, hooting tone. It was therefore found necessary to reduce the width of mouth to two-ninths or even a fifth of the circumference. The languid was also given an acuter bevel as in Fig. 3C. Meanwhile the firm of Lewis and Co. were producing a fine type of diapason on the same pressures as Schulze had employed but with a fourth mouth. James Jepson Binns was also doing much the same; and the diapasons of these two firms were of a very high order of excellence. There was a difference between Lewis and Binns in that the latter did not fully "wind" his pipes, while Lewis invariably followed Schulze in giving his diapasons the maximum flush of wind from the pallet. I well remember Mr. Binns writing to tell me how surprised he was to find that Schulze "had got the full tone out of every pipe" on the great organ at Armley. Nevertheless, Binns produced some very fine diapasons in a large number of his organs, examples of which may be found untouched in the School Chapel at Tonbridge, at the Albert Hall, Nottingham, and at Rochdale Town Hall. His pipes were made of thicker metal than those of Schulze or of Lewis. Now these modifications of the Schulze type do not properly belong to this section and are only mentioned in justice to the work of two highly esteemed builders and as the last of the low or moderate pressure school of diapason voicing. These were succeeded by large-scaled diapasons, heavily winded with well cut up narrow mouths, giving a blustering, hooting tone of considerable ugliness. In order to mitigate these defects two methods were adopted. First, James W. Walker, employing for his No. 1 diapason a large scale at the 8 ft. pipe, reduced that scale at tenor C and again at middle C in proportion to the preceding octave, and

widened the flue, pulling out the upper lip to suit. With wind pressures varying between 4½ in. and 6 in. he was able to obtain a big foundational tone free from windiness or hootiness, and whatever criticism these diapasons may have evoked—and I admit to having severely criticised them at the time—they undoubtedly had a wonderful effect in a large building. I remember being greatly impressed by the effect of the Walker diapasons in this firm's rebuild of the organ in York Minster when Dr. Tertius Noble was organist; while at Holy Trinity Church, Finchley Road, Hampstead (London), there are two large diapasons on the great organ, one of the type just described, the other with a well developed harmonic content supplying the necessary richness of tone to the unison foundation. The effect of these two stops in combination in this resonant building is magnificent. I take my hat off in deep respect to the late lamented James W. Walker, and it is due to the memory of a great artist that his achievements should be fully acknowledged. Secondly, there came the "leathered upper lip," adopted systematically under the name of "diapason phonon" by Robert Hope-Jones in the nineties. This certainly solved the problem of the overblown pipe. The lining of the edge of the upper lip with a soft substance considerably reduces the energy of the vortices as already explained in the previous chapter and also damps the formant frequencies. The object of the leathered lip was, as Hope-Jones stated, to reintroduce the "full, rolling effect of the old diapason work of Father Smith and Renatus Harris." The "full, rolling effect" was reintroduced in conjunction with greatly increased power. That was the claim, and the claim was substantiated. At first, the scaling was too large, but later it was modified, and examples are to be found in the organs of Messrs. Harrison and Harrison, the John Compton Organ Co., and Norman and Beard (now Hill, Norman and Beard). The leathered lip diapason also found its way to America, together with large scales and heavy pressure; but a trend is developing in the opposite direction in favour of a richer and less foundational type. The chief drawback to this kind of diapason is its reluctance to cohere with the octave ranks of its family: the harmonic content of the unison is not sufficiently developed to enable a complete chorus to be built up on its platform. It is not possible to leather the lips of pipes above the limit of treble C without ruining the speech and enfeebling the pipe, so that in order to extend the characteristic quality of the leathered pipe to the upper register it is necessary to curtail the harmonics of the higher-pitched pipes by cutting up or increasing scaling. If this is not done and the smaller pipes are allowed their full quota of harmonics, a hiatus occurs between the unison and the upper work and cohesion between the various ranks is impossible. This is my own view of the matter, and it may be that I am wrong. If I am, my ears are telling me lies: moreover, the theory that cohesion is only possible between ranks of pipes possessing the same or a similar harmonic characteristic is a mistaken one. But is it? I venture to say that it is in accord with Nature's own law. The oscillograph will prove its correctness.

Having stated my objections to the leathered lip method of voicing, I have to confess that I have derived considerable aesthetic enjoyment from several individual examples of this type of diapason voiced by our modern English builders, especially those which have been enclosed in swell boxes. It is mainly on account of their unsuitability in a diapason chorus that I part company with those who advocate them; and it has to be borne in mind that the device of leathering is entirely unnecessary if **low or moderate wind pressures are employed.** The whole subject of diapason treatment in connection with the unison rank is inextricably bound up with the wind pressure question, and the wind pressure question is in turn bound up with the architectural problem. Shall the unison rank predominate in the series from double to twenty-second? Is it necessary to make the unison rank so very powerful or to give it so massive a tone? That is the crux of the whole tonal situation presented to modern organ building. I shall postpone the answer, or an attempt at an answer, to the chapter on Tonal Architecture: this is not the place to discuss the question. Suffice it to say that a diapason may be *per se* a magnificent piece of work betraying the highest possible skill on the part of its producer, yet may be entirely unsuitable as a link in the tonal chain. It will in these circumstances find its appropriate niche in the solo department rather than take its place with the diapason family of the "diapason organ."

7. The invention of the "double languid" by Vincent Willis and the "tubeon" by Grindrod made possible a special type of diapason of great power and richness. The double languid has been described in the previous chapter. It was first introduced in an actual organ by Henry Willis, the present head of this famous house, namely on the great manual of the large west end organ at Westminster Cathedral. Another example occurs in the Willis organ in Liverpool Cathedral, and another in that of Hanley Town Hall. The Westminster stop has the following scale: 4 ft. C, 4¼ in., 2 ft. C 2½ in., width of mouth being two-ninths of the circumference, the cut up four-elevenths of the width. The wind pressure is 12 in., and the actual power is prodigious. The quality is inclined to be hard and metallic at close quarters, and I believe that Mr. Willis now prefers the result obtained from fitting "amplifiers" (or compensators) to the tops of single languid pipes. In the fourteen hundred stop organ of the Atlantic City Auditorium, New Jersey, there are two complete sets of double languid diapasons from 16 ft. to 2 ft. on 20 in. and 12 in. respectively. These were voiced and finished by Mr. Vincent Willis (the son of the inventor) who went to America at the invitation of the Midmer Losh Company and of Senator Emerson Richards (the builders and the architect respectively of this huge instrument). I was also paid the very high compliment of being asked to go out there and superintend the voicing and finishing of the "Schulze diapason chorus" of this organ, but was unable to leave London at the time owing to engagements which had a prior claim upon my person. Naturally, in a hall which is able to accommodate 40,000 people it was necessary to provide in the specification tones of exceptional power, and the double languid stops on 20 in. pressure must surely be the most stupendous diapasons in the world.

It was in, I think, 1932 that Mr. Willis, while carrying out a series of experiments in the voicing shop at the Ferndale Road factory ("the Rotunda") in Brixton, made the discovery that by fitting a cylindrical sleeve over the top of an open string-toned pipe so that the sleeve overlapped the top and was approximately 25 per cent. wider than the diameter of the pipe, the note given by the pipe was increased in power and harmonic content, and also spoke with great promptness. A small-scaled string-toned pipe (a viol) voiced to speak on a pressure of 5 in. could, by this treatment, have its pressure raised to as much as 10 in. and still speak promptly and firmly without overblowing, and without any re-adjusting of the parts. An open diapason pipe of large scale and cut up too high to give its natural harmonics on a moderate wind pressure, with a tendency to "cough" its note prior to mature speech, could be cured of its faults by the fitting of this device. It was, however, later discovered that the idea had been patented by Grindrod under the title of "the tubeon," and I well remember seeing Mr. Grindrod's advertisement in *The Musical News* in the early nineties, though I did not know what the "tubeon" was. Mr. Willis introduced a variant of the device in the form of a tube of **narrower** diameter fitted inside the top of the pipe, the diameter of this tube being approximately half that of the pipe. I am not aware that the "tubeon" or the "compensator" has ever been applied to a stop of organ pipes before Mr. Willis introduced it in his own organs; it is certain that I have never encountered an example in any organ of my acquaintance before 1932. Mr. Willis has applied it to several diapasons, notably to the diapason chorus on the great manual of the Birmingham Town Hall organ which he rebuilt at this time. The finest example of a large diapason so treated occurred in the fine Willis organ in the Colston Hall, Bristol—now, alas, destroyed. I have used the compensator in the treatment of my "super diapason" at Stagsden Parish Church—an interesting example of a diapason standing on a soundboard of its own of exactly similar design and construction as that at Micheldean Parish Church (referred to in section 3), and speaking on a pressure of 2½ in. only. The stop measures 6 in. at CC (8 ft.), 3½ in. at tenor C (4 ft.), and 2⅛ in. at middle C (2 ft.). The lowest octave and all the pipes with the exception of the tenor octave have fourth mouths, the tenor octave having two-sevenths mouths. The compensators are fitted to all the pipes from tenor C to treble F. I found that when added the compensators unduly augmented the higher harmonics, the pressure being then 2¾ in. The stop was also too powerful for the size of the church. This entailed reducing the pressure to 2½ in. and also cutting up the mouths of the pipes from middle C to treble F so as to be a **third** of their width instead of two-sevenths: even then I was not quite satisfied with the result. I accordingly burnished the **posterior** edge of the upper lip of each pipe from tenor D sharp to treble F. The quality of tone is peculiar to the stop: I know of no other diapason that gives the same effect. It blends admirably with the 4 ft. principal (octave diapason) though the latter is of much smaller scale. The compensators are not required above treble F in this particular case.

With regard to the dimensions of the compensator and its adjustment, a few words are necessary. If the cylinder is made of larger diameter than the pipe to which it is fitted, it is normally a quarter more in diameter than the diameter of the pipe. In order that the pipe may be tuned, it is convenient to solder the compensator to the usual tuning slide. If the length of the compensator tube is twice the diameter of the pipe (as it should be), it may be soldered to a point about half-way up the tuning slide. Fig. 5A shows this quite clearly. The question now arises as to the degree of overlap permissible. If the compensator is so adjusted that it projects above the top of the pipe by the distance of the pipe's diameter (the "half overlap" position), the note is amplified with increase of fundamental and harmonics in proportion. If the overlap is equal to a quarter of the length of the compensator, the harmonic content is increased but not the fundamental. A three-quarter overlap increases the fundamental at the expense of the harmonics: a sixteenth overlap merely stabilises the speech of the pipe. Obviously the "end correction" of the open pipe at its top is affected variously by the degree of overlap employed, as explained in the previous chapter. In my super diapason I did not adhere meticulously to the above-mentioned rule as to the diameter of the compensator but varied the relative sizes at each succeeding octave, as also the degree of overlap. The smaller pipes require much wider tubes in relation to the scale than the larger pipes if the compensator is to be effective.

On the whole, however, I am of opinion that the compensator needs to be used with great discretion, and certainly not indiscriminately for the sake of increased power or effect. My "cowl" when applied possesses certain advantages in that it does not augment the **higher** harmonics, but increases the fundamental plus the harmonics up to the twelfth partial. It may be connected by means of legs to the tuning slide as shown in Fig. 5B. The distance between the top of the tuning slide and the bottom of the cowl should be normally a quarter of the pipe's diameter for a diapason. Owing to the difficulty of obtaining the requisite material at the time, I did not fit cowls to my super diapason, though I had been able to fit them to my trumpet pipes (to which I have already referred in the previous chapter). In Fig. 5B it will be noticed that the diameter of the cowl is **slightly** in excess of that of the pipe: this is as it should be.

8. The geigen diapason is, as its name implies, of German origin, being introduced into this country by Edmund Schulze. The harmonic curve of an American-made geigen pipe is shown in Fig. 7. If string tone in moderation is desired from a diapason the geigen is the best stop for the purpose. As already pointed out, the basic difference between the geigen and any pipe giving string tone (that is, a viol or a salicional) lies in the amplitude of the fundamental in relation to that of the other harmonics. The geigen is a diapason for the simple and all-sufficient reason that its fundamental harmonic predominates in the harmonic series, while the fundamental harmonic of the viol or the salicional is weaker than third and fourth harmonics (and not infrequently weaker than the second). The geigen is a very beautiful stop if properly scaled and voiced—an exceedingly rare event. In nine cases out of ten the so-called ''geigen'' is as different from the geigen of Schulze as chalk is from cheese: the quality is hard and horny, with all the characteristics of a forced note. I am not alluding to the slotted variety, often labelled ''violin diapason,'' nor to the slotted ''horn diapason'' of slightly larger scale which was much in favour in Victorian organs. The fact is that the true geigen quality can only be obtained from the barred and grooved chest or from a chest of similar design which allows the wind supply to the pipe to build up to its settling pressure in the foot and flue without the initial pressure drop due to the opening of the pallet or valve (see chapter on ''Soundboards''). The manner in which the pipe is supplied with wind affects the formant content rather than the natural harmonics, though the latter may be indirectly affected. In any case the pipe should be made to speak with absolute naturalness and its articulation should be prompt without a trace of ''spit.'' The nicking should be very fine and close, the flue carefully adjusted to the precise width, the upper lip kept concave with a sharp **posterior** edge and a slightly curved anterior edge. The foot-holes should be so adjusted in size as to enable the pipes to speak quite naturally: the ''peak tone'' must never be obtained from the pipe. And at least fifty per cent. of tin must be used in the metal alloy. The width of mouth is best from four-fifteenths to two-sevenths of the circumference with a cut up not exceeding four-fifteenths of the width (or two-ninths of the diameter) whatever the pressure, which latter should never exceed 3½ in. A ''beard'' is essential in front of the mouth, and by a beard I do **not** mean a roller-bridge, but a flat strip of metal soldered across the lower portion of the outside edge of the ears. If a similar piece of metal is soldered to the underside of the ears, this is called a ''fender,'' being a ''continuation of the ears,'' as the late William Whiteley termed it. To sum up the conditions of a successful voicing of the true geigen, attention must be paid to (1) the design of the soundboard, (2) the mouth area, (3) the material of which the pipes are made, (4) the treatment of the upper lip, (5) the nicking (25 nicks to the inch at the optimum depth), (6) the right size of foot-hole, (7) the wind pressure, (8) the scaling, absolute and relative, and (9) the beard As regards the scale, it should not exceed 4½ in. at CC (8 ft.), 2¾ in.

at tenor C (4 ft.), 1-11/16 in. at middle C (2 ft.); and a smaller scale is desirable namely, 2⅝ in. at the 4 ft. pipe and 1⅝ in. at the 2 ft. pipe. Schulze invariably cut up the mouths of his geigens a fifth of the diameter of the pipe: this is equivalent to two-ninths of the width of the mouth, assuming the width to be two-sevenths of the circumference.

We must now turn our attention to the CC octave of the diapason. It is generally recognised that all manual flue stops possess their more distinctive characteristics from the 4 ft. pipe upwards. For this reason the lowest twelve pipes of a manual stop are given special treatment, a treatment which is not necessarily the same as that given to the remainder of the pipes above BB. Moreover, the notes of the bottom octave possess their own characteristic by reason of their pitch, though it is highly probable that they owe the characteristic in great measure to the fact that the human ear is able to detect more easily their higher harmonics. Be this as it may, organ builders are accustomed to dealing with these larger and longer pipes as a distinctive class and speak of "matching the bass to the tenor C portion of the stop." It is a well known fact that the tenor octave of a diapason tends to become more "foundational" in tone than the notes from middle C up, and that the lowest octave of the manual tends to become more "stringy." This is particularly the case when a diapason is voiced on the fluty side, that is, if it is made foundational and its harmonic development is not encouraged. In such a case the lowest octave tends to stand out unduly with its natural harmonic development unimpaired and therefore not matched in tone to the upper portion of the stop. An early English type of diapason should be given its appropriate bass, which may very easily have too pronounced a harmonic content. The mouths of the CC to BB octave should be cut up higher than those of the higher-pitched pipes, and in no circumstances should zinc be employed for the bass. A wood bass is entirely suitable if voiced to give a fluty tone with a very small modicum of harmonics. The ideal method is to carry the plain metal pipes down to GG and continue in either plain metal with higher cut mouths or in wood. The scale suggested for the CC pipe is 5½ in. with a fourth mouth cut up a full third of its width on a pressure not exceeding 3 in., the size of the foot-hole being carefully adjusted to the pressure. The wood CC pipe may measure 5 in. square (inside), or 5½ in. by 4⅞ in. with the mouth on the narrow side and cut up a fourth of the width of that side. The shape of block and cap is shown in Plate II D or F. For the metal pipe an inverted languid as shown in Fig. 3D is very suitable for this type of tone.

The bass of the Schulze type of diapason is best made of wood, and the models illustrated in Plate II at D, E, or F are all suitable. The CC (8 ft.) pipe of the No. 1 diapason at Hindley measures 4⅜ in. by 4¼ in (inside), the mouth being cut up 1 in. and fitted with a bridge. A metal pipe at CC would measure 5⅝ in., but allowance has to be made for the influence of wood on the harmonic development of the pipe, so that the wood pipe is made about four or five pipes smaller than the corresponding metal one. But all depends on the quality of tone sought, some voicers preferring the richer tone of the smaller scaled pipe to the fuller tone of one made a pipe or two larger. Thus, it is perfectly in order, if so desired, to scale the CC pipe of the above-mentioned diapason (which is 3⅜ in. at the tenor C 4 ft. note) 5¼ in. square so as to get a bigger percentage of fundamental in the tone. It will be noted that I recommended as much as 5 in. square for the CC pipe of the early English diapason with a similar type of block and cap, but the wind pressure would be lower and the mouth cut up rather higher, namely a fourth of the width of the narrow plank (if the pipe is rectangular); while the cut up for the

Schulze wood pipe is two-ninths of the width of the pipe (inside). The bridge is fitted to all these pipes, though it is not shown at E and F in Plate II. Note that the block is made to slant back away from the cap in all cases, an essential condition for the development of harmonics from a wood pipe. The top of the cap is set flush with the top of the block: hence no notching is required. The late Thomas Pendlebury, who made a speciality of wood pipes of string tone, and was a great artist, used to raise the top of the block slightly above the level of the cap with a front bevel such as is given to the metal languid: he notched the front edge of the block and also the corresponding inside portion of the cap, blackleading both surfaces. The portion of the bridge facing the mouth was given a parabolic curve instead of the more usual rounding. Plate II H shows one of these pipes, while the notching of a wood pipe block is shown at L.

It is, of course, quite permissible to employ metal for the bottom octave of any diapason, even for the Schulze type, in which case the question of relative scaling (in reference to the tenor C scale) has to be determined by the voicer. It is a common practice to increase the ratio in order to ascertain the inside diameter of the 8 ft. pipe. In other words, if we adopt a pipe to pipe ratio of "half on the seventeenth note" for the relative scaling of our diapason from tenor C to top note—and I think this is the best ratio for all general purposes—then normally we should divide the diameter of the tenor C pipe by 5/3 in order to ascertain the diameter of the CC pipe. This is what Schulze invariably did. Thus, his 3¾ in. tenor C pipe was matched at CC by a 6¼ in. scale, and his 3½ in. pipe by a 6 in. scale, and so on. But many builders prefer to adopt a rather bigger scale for the bottom octave, and the firm of J. W. Walker and Sons were at one time noted for the large scales employed in this octave. The No. 1 diapason of the fine organ in Holy Trinity Church, Sloane Street, London, measured as much as 9 in. at CC; and many examples exist of diapason basses with the CC pipe measuring 7½ in. inside. There is reason for this. The majority of diapason basses were and still are made of hard-rolled, stout zinc; and in order to obtain the desirable weight and fullness of tone from the zinc pipe it was found necessary to increase the scale. The lips of the pipe are usually made of plain metal and soldered in position, since zinc is the worst kind of metal for the mouth of a diapason pipe. Obviously, zinc is lighter than plain metal and less expensive; moreover, it lasts longer. The feet of plain or spotted metal pipes of this size are apt to sink at the toe end or to sag in the middle owing to the excessive weight of the pipe-body. The late T. C. Lewis was very partial to spotted metal for all his large pipes down to the CCC (16 ft.) pipe, but in any case the price of tin to-day makes an organ builder hesitate to employ spotted metal below tenor C (4 ft.). The thickness of zinc sheet for these pipes should not be less than a sixteenth of an inch. It is usual to cut up the mouth a third of its width, whatever the width (from two-ninths to a fourth of the circumference), and then increase the height to four-elevenths if required. The voicing of diapason basses is an expert job and requires an experienced hand. This may, of course, be said of all voicing, but to ruin a large and costly pipe is a tragedy.

Finally, how can we meet the 4 ft. pipe in our scaling of the twelve pipes from CC to BB? An organ builder or a pipe-maker would not need to be told the answer! But this book is primarily written for the enquiring amateur, and I have often been asked this kind of question—"Please give me a rough-and-ready rule for the diameter of each pipe in the lowest octave of a diapason." I therefore suggest the following method which I can vouch for as reasonably satisfactory. Taking the inside diameter of the tenor C (4 ft.) pipe as given, write down on a sheet of paper in a horizontal straight line the thirteen successive notes from tenor C to CC. Under the note G♯ write the figure 4: this is the datum point and represents the 4 in. diameter pipe. Next reduce the diameters of each note **above** G♯ by steps of ⅛ in., and the diameter of each note **below** G♯ by steps of ¼ in. Carrying out this process with a given diameter of 3½ in for the tenor C pipe, we get the following result:—

T.C	B	A♯	A	G♯	G	F♯	F	E	D♯	D	C♯	CC
3½	3⅝	3¾	3⅞	4	4¼	4½	4¾	5	5¼	5½	5¾	6

If we choose the scale of 3¾ in. for our tenor C pipe, we shall find that by adding ⅛ in. to each successive pipe we arrive at the 4 in. datum at A sharp, that is the third pipe from tenor C. Therefore we proceed to add ¼ in. to each successive pipe beyond A sharp and finally reach CC with a diameter of 6¼ in. Thus, the 4 in. datum may be shifted along the line according to the diameter chosen for tenor C, and the successive steps of ⅛ in. or ¼ in. can easily be calculated to the left and the right of the 4 in. datum point. This is, admittedly, a rough-and-ready method of working out the diameters, but that is what I was asked for; and it *works.*

The diapason can be extended down to the 16 ft. pipe and up to the three-quarter-inch pipe. (I am not taking into account the 32 ft. pipe in this chapter.) Thus, a family of diapasons will consist of double, unison, octave, superoctave and twenty-second, or we may call them diapasons 16 ft., 8 ft., 4 ft., 2 ft., and 1 ft. There are also "off-unison" ranks or "mutations," such as the fifth or quint, the twelfth, the tierce or seventeenth, the nineteenth or larigot, the flat twenty-first or septime: but these and all the octave ranks above the unison will be considered in Chapter VII. The **double diapason** must, however, receive some attention in this section in order to complete our survey of the diapason pipe. We can, of course, add twelve lower notes to the 8 ft. stop, thus carrying it down to the 16 ft. pipe. By arranging a suboctave coupler to work on the unison rank we could get both 8 ft. and 16 ft. diapasons in combination. It would be possible to construct a chest to hold 85 pipes from 16 ft. to the top pipe of the 4 ft. rank: then employing a suboctave and a superoctave coupler, with a unison off coupler, we could use the stop in either 16 ft. or 8 ft. or 4 ft. pitch, or all three pitches in combination. In other words, it would be possible to provide by this means a "family" of diapasons in 16 ft., 8 ft. and 4 ft. pitch. Whether this would be a desirable method or not is a question I do not propose to discuss now: what I am concerned to show is that we can derive a sufficiently clear idea of the construction and treatment of the octave diapason from a study of the upper portion of the unison rank, and likewise of the construction and treatment of the suboctave rank (or double diapason) from a study of the lower portion of the unison rank. However, it will be found from practical experience that for the double, at any rate, the best result is obtained from a set of pipes which do not duplicate the lower half of the unison rank, since the power and weight of tone which is suitable for the bass of the unison rank would be too much for the double and produce in combination with the unison rank a bottom-heavy effect. In any case, therefore, the double needs to be subordinated in power to the unison, at least as far as the three lowest octaves are concerned. Basically, the pipes would be constructed on the lines of the 8 ft. bass octave already described, in wood or in metal (as desired). A good scale for the 16 ft. metal pipe, usually made of zinc in these days of high prices, would be 10 in., though it may be anything between the limits of 9 and 12 in., with a two-ninths mouth. The wood pipe would be 10 in. by 8 in. with a roller-bridge, and not less than 9 by 7 in., in order to avoid stringiness. From middle C up metal pipes are best, the scaling being adapted to suit each special case.

Miniature Diapasons. These are the **dulciana, salicional diapason,** and **gemshorn.** It is always possible, however, to convert a large-toned diapason into a miniature version by enclosing it in what Dr. Audsley used to call "an annihilating swell box." I have myself transferred a big No. 1 diapason from its position on the great manual soundboard to another soundboard in the swell manual box: the stop was transformed into an echo diapason **even with the shutters of that swell box fully open.** Again, a large diapason designed to give full power on the great manual may be "annihilated" by its position behind a heavily panelled case or a stone screen or colonnade. The late Sir Frederick Bridge used facetiously to call the Westminster Abbey diapasons on the great "the Abbey dulcianas." They were, as I remember, obscured by the fine case (designed by J. L. Pearson) which was removed when the organ was rebuilt for the Coronation of our present King. Poor William Thynne wept tears of chagrin and disappointment on hearing the ridiculously attenuated effect of his great No. 1 diapason at St. John's, Richmond. "It was simply terrific in the shop" was his remark, "and now, where, oh where has it gone to?" Yes indeed, an organ builder has to suffer many a similar disappointment when his "lovely pipes" are transported to their final home in acoustical surroundings that successfully emasculate them and deprive them of any chance of displaying their intrinsic virtues. Diapasons may only too easily become dulcianas, though, to be sure, that is a desirable thing in some cases where the blending properties of the stop are non-existent.

The **dulciana** (invented by Snetzler) is a real echo diapason. The pipe is illustrated in Plate I. The scale is small, a standard measurement being 2 in. at tenor C (4 ft.) with a fifth mouth cut up a fifth of the diameter. The CC (8 ft.) pipe is, therefore, 3⅛ in., though some voicers prefer a rather larger diameter such as 3¼ in. The foot-holes are kept quite small, the flue is narrow, and the nicking fine and close. The dulciana is very apt to "spit" and "cough" owing to the smallness of its scaling and mouth-area in relation to the power of the note permissible: in other words, a slight increase of the size of the foot-hole will usually cure these faults, **but the pipe will probably be too loud in speech** after this expedient has been resorted to. **The only true remedy is to deepen the nicking very slightly.** This latter is a delicate operation for the novice to attempt, though child's play to an experienced voicer: it is fatal to overdo it, but a perfect remedy when skilfully applied. The dulciana is easily **the most difficult of all organ stops to regulate to a nicety.** Here is **the** acid test of the would-be finisher: give him a dulciana to regulate and judge him by the result! My friend, Mr. H. B. Weatherdon, Mus.B., F.R.C.O., at one time organist of St. Peter-in-the-Forest, Walthamstow, many years ago requested me to regulate his dulciana (unenclosed) which was very uneven. "What do you want me to do to it?" I asked him. Then came the thunderbolt. "Make it like Arthur Harrison would if he were here." That was a tall order. However, I essayed to emulate the great finisher in my humble fashion—this is not mock humility, for I **know** I shall never attain to Arthur Harrison's consummate skill in this particular domain of the fine art—and whether I succeeded or not I cannot say. I can only remember Mr. Weatherdon's beautiful improvisation on this stop as I listened at the other end of the church entranced by the artistry of another. The dulciana is one of the most beautiful of all organ stops: my father—the founder of Trinity College of Music—used to say: "This is real organ tone." It is, for after all it is real diapason tone in miniature when properly voiced and finished. It lacks the dash of string tone detectable in the voice of the viole sourdine or the salicional, and keeps delightfully within the precincts of its own diapason class. A double dulciana, 16 ft. is also a delicious little double for soft combinations, the 16 ft. octave of pipes being scaled in the ratio of half on the seventeenth as all the other octaves are. This makes the diameter 5½ in. for the 16 ft. pipe. Some voicers prefer a larger scale giving a more firm and pronounced fundamental: I have seen a scale of 6 in. for the lowest C in several organs. The foot-hole is very small, and the mouth is "fendered" in some cases and "bearded" in others. Zinc is quite permissible for the two lowest octaves, which should always be fitted with beards or rollers. Wood is sometimes employed for these octaves, the scale at 16 ft. being of the order of 6 in. by 5 in. or 6 in. square; the formation of the mouth parts being as shown at E, F, G, or H in Plate II.

The **salicional diapason** (so called by me to distinguish it from the salicional described in Chapter IV) is a small-scaled diapason with a narrow mouth. It is the narrow mouth that is essential to the type. Lewis used to make very beautiful examples of this stop for his choir organs: the pipes had two-elevenths mouth-widths, cut up two-ninths of the diameter. The tenor octave must be fitted with beards or with rollers, and the CC octave treated as a slightly larger edition of the dulciana, with a scale of 3⅜ in. (or 3½ in.) for the 8 ft. pipe. The fifth mouth salicional diapason is also excellent with suitable treatment: it thus becomes a dulciana on a larger scale. The double salicional diapason is in reality just such a stop in 16 ft. pitch, the 16 ft. bass octave being treated exactly like the corresponding octave of the double dulciana with the 6 in. scale above mentioned as favoured by certain voicers. The resemblance between the dulciana and salicional **basses** affords an exemplification of my earlier comment in this chapter on the desirability of regarding all flue stops as possessing their more distinctive characteristics from the 4 ft. pipe upwards (see page 45). The octaves of the dulciana and salicional diapason are often called **dulcet and salicet** respectively.

The **gemshorn** has a tapering or conical shape of body as illustrated in Plate I over the title "muted viol." (The latter stop is very much narrower in formation, however, and belongs to the miniature string category). The diameter of the top of the tube is usually a third of that at the mouth, though it may be a half or a fourth according to the voicer's caprice. There can be no doubt that this particular form of pipe alters the characteristic by reducing the amplitudes of the third and fourth harmonics, while the ninth and eleventh are slightly reinforced. The fundamental is unaffected by the taper, and so is the octave (second harmonic)—thus the diapason characteristic is maintained as formulated on page 29.

Another interesting feature of the harmonic content of the gemshorn is the "harmonic cut-off" at the fourteenth partial, whereas the cylindrical low pressure diapason normally extends its harmonic range up to the twentieth partial. (The 19th and 20th harmonics are very weak). The quality of the gemshorn is very difficult to describe in words: it is hardly true to say that it is "horny" (despite the name "goat's horn"). My friend William Arthur Barr used to solve the problem of finding a suitable description by calling it a "cony tone"! "It says to me 'cone, cone'—was his comment. And at that I leave it. The really successful gemshorn must be very moderate in power; hence it **should** belong to the category of miniature diapasons, whether in 8 ft. or 4 ft. pitch. A good scale is 3 in. at the mouth of a 4 ft. pipe, with a fourth mouth cut up a third at most. The 8 ft. octave can, of course, be made of tapering pipes (as at Armley), but this is quite unnecessary. Here again we observe the effect of pitch on the characteristic quality of a flue stop: below the 4 ft. note the distinctive character fades into a more common mould as far as the human ear is concerned. The **spitzflöte** (spiral flute) is a variant of the gemshorn, and though there are organ builders who will assure us that a "spitzflöte is not a gemshorn" there is nothing to prevent anyone from making a gemshorn and labelling it a spitzflöte, or *vice versa*. The only real difference that can be made between the two is by carrying the cylindrical portion of the body a short distance up from the mouth line and then soldering a cone on to the top of this to complete the speaking-length. A pipe-body of this kind is illustrated in Fig. 5D, though the top would not be capped as shown there. In any case it must be distinctly understood that the spitzflöte is not a flute. A good story was told me by a well known builder who had been "ordered" to put in a 4 ft. harmonic flute on the great manual in place of the essential principal or octave diapason. The builder protested vigorously. The "expert" responsible to the organ committee for the specification of the instrument and the carrying out of the contract was adamant: a flute he must insist on having. At length, his reputation at stake and in despair of convincing the expert of the error of his opinion, the builder said: "Well, Mr. . . . ., I suppose I'll have to give way and put in that flute: I presume you have no objection to a spitz**flute**?" No, there was no objection at all; and in it went. But it was a 4 ft. diapason after all.

CHAPTER III

The Strings

THE string-toned stops of the Organ are a comparatively recent development in the history of organ building. Harmonics are well to the fore in this category of tone, right up to the thirtieth partial. But a price has to be paid for this harmonic development. The first harmonic or fundamental is relatively weak, as a glance at the graph of Fig. 7 shows. The fourth harmonic is the strongest and thereafter a gradual decrement of harmonics occurs. Thus, one of the analytical charts prepared by Dr. Boner giving the harmonic content of a viol pipe, middle C, of standard pattern and voicing, discloses the following series of amplitudes along the harmonic train:

Harmonic	Approximate Percentage	Harmonic	Approximate Percentage	Harmonic	Approximate Percentage
1	48	11	11	21	1
2	62	12	13	22	1
3	48	13	4	23	1
4	100	14	4	24	1
5	25	15	3	25	1
6	25	16	3	26	½
7	30	17	2	27	½
8	15	18	2	28	¾
9	18	19	1	29	⅓
10	18	20	1	30	¼

Analysis of another sample pipe shows the second harmonic to be the strongest, but the fourth is always stronger than the fundamental. The characteristic quality of the organ flue pipe giving string tone is therefore a relatively weak fundamental with the second and fourth harmonics predominant and a long train of harmonics following. A tone equipped with a large retinue of harmonics is not necessarily of the string category, since reeds are capable of producing a plethora of harmonics as we shall see in our next chapter; but the amplitudes work out differently in either case, resulting in two different curves. The organ pipe cannot really reproduce the actual string tone of the violin or viola because the orchestral instrument has a pronounced fundamental due to the belly or resonator. For this and other reasons the organ viol approaches the oboe more closely than the violin. But in any case the quality produced by string-toned pipes is peculiar to the Organ and must be recognised as such. There is no discredit attaching to the failure of organ stops to reproduce the tones of rival instruments. It would be possible to give all organ stops quite different names from those to which we are accustomed, but there is no point in doing so. A violinist and a trumpeter once asked if they could hear their own instruments played on the organ. The organist complied with their request and drawing the **viole d'orchestre** played a few notes; then drawing the **trumpet** he repeated the passage. The violinist and the trumpeter both shook their heads sadly. "No resemblance whatever," was their verdict. Of course not. Why then give such well known names to stops that do not claim any real tonal resemblance to their prototypes? The reason is a psychological one. At first each fresh acquisition in the tonal domain of the Organ was hailed as an imitation of some orchestral or well known instrument because **compared with the diapason** the new tone could put up some sort of claim to affinity with its prototype. The blare of the trumpet and the richness of the viol made comparison possible in each case. All that is necessary now that we recognise the basic differences is to agree to allow to the organ and the orchestra their own instrumental nomenclature respectively without the least spirit of rivalry, admitting that the organ viol is not a violin nor the organ trumpet a player's trumpet. The strings of the Organ are instantly recognisable, just as are the diapasons and the flutes. This is all that really matters.

The early examples of string tone were severely handicapped by the absence of the roller-bridge. The roller-bridge is essential to prompt speech if the harmonic development of the pipe is to be conserved. The function of this device has already been explained in Chapter I. Without it the voicer is tied down to a large scale and a high mouth to avoid overblowing: the harmonics are then reduced and the tone becomes "edgeless." William Hill introduced the conical pipe surmounted by a bell (or inverted cone), which is tantamount to the fitting of a bell to the gemshorn with the object of making it more stringy in quality. This is the original **viola da gamba**; its tone is peculiar and not very attractive. I do not know of a single builder who now makes it. To keep it in tune it is necessary to adjust the ears (made extra large for this purpose), and this alone is a serious drawback.

The modern viol is of relatively small scale (compared with that of the diapason) and the scale varies according to the power and character required. Take a dulciana pipe, middle C, 2 ft. with a diameter of 1-3/16 in. and a fifth mouth. It is desired to convert this pipe into a violoncello speaking the same note. At present the mouth is cut up a fifth of its diameter, that is a bare ¼ in. high. We proceed to cut up the mouth to a height corresponding to a third of its diameter, namely ⅜ in. We next enlarge the foot-hole till on the pressure of wind delivered to the foot from the soundboard the pipe overblows to its octave (becoming a flauto traverso!). In order to restore the note to its fundamental pitch we fit a roller. This roller may be a piece of round stick of hard wood a quarter of an inch in diameter, or it may be of metal instead of wood. The novice must use wood, because a metal roller has to be soldered in position to the ears of the pipe, and once soldered must remain there, whereas the wooden roller can be adjusted, then fastened to each ear by means of a small brad. It can be rotated to the correct position between the ears and finally a second brad can be added at each end to secure it permanently. The position of the roller is first found by experiment. The roller is held by the fingers in front of the mouth of the pipe while it is sounding its octave and then pushed in between the ears, being placed nearer to the flue and lower lip than the upper lip, yet still leaving a small space underneath the roller for outside air to reach the flue. It is slowly pushed forward towards the mouth until the pipe speaks its middle C note instead of its octave. When the pipe does this it will return to its rightful pitch "laden with harmonics." The ears of the dulciana pipe will probably be rather small for holding the roller, part of which will project beyond the outside edge of each ear (towards the voicer). The languid may have to be lowered slightly, the flue made a little wider and/or the upper lip brought out a trifle, before the pipe can be passed by the voicer as satisfactory in attack and tone. If a narrow slot is cut out at the top of the pipe at a distance of the pipe's diameter from the top, the slot being a quarter of the diameter in width and 1½ in. long (vertically), the tone will become keener still. But the pitch will be sharpened by the cutting of the slot and the pipe will have to be tuned to give C sharp instead of C, with a tuning slide fitted round the slotted portion and leaving the upper part of the slot uncovered. Instead of the slot a "compensator" may be fitted to the top of the pipe, in which case the middle C pitch can be preserved and the note will be both richer and louder. If the wind pressure is increased and/or the size of the foot-hole, a still bigger tone can be produced from the pipe by cutting up the mouth still higher. There is, of course, a limit beyond which this process cannot go: it is the experimenter's business to ascertain that limit. Before it is actually reached the quality of tone will have become coarse, even though the pipe may be speaking promptly.

Real string tone was unknown in this country prior to the introduction by Schulze of his wood string stops. Of these I will speak later. As far as the metal string pipe is concerned we are indebted to William Thynne for his pioneer work in this direction. He introduced the first **viole d'orchestre** in the Michell and Thynne Exhibition organ of 1885 (now the "Grove Organ" in Tewkesbury Abbey), with its partner celeste rank (another viole d'orchestre tuned sharp to beat with it). The scale of the bottom CC pipe is 2½ in., that of the tenor C pipe being 1½ in., and the middle C 15/16 in. The width of mouth graduates from two-ninths in the lowest octave to a third in the top octave: this extreme width is responsible for the comparatively fluty quality of the treble register (in imitation of the orchestral instrument). The pipes are all slotted and, of course, rollered. It is the opinion of many connoisseurs that there has been no greater voicer of metal string pipes than Thynne, an opinion with which I am in cordial agreement. He died at his voicing machine, broken-hearted at his failure to win the recognition that he deemed he deserved. Like so many great artists he won that recognition posthumously, and it is to be hoped that every surviving example of his work will be jealously guarded and preserved from vandal hands. Perhaps his finest work was that of the organ in St. John's, Richmond, where the viol (in the swell) is 2⅞ in. at CC, and 1⅝ in. at tenor C.

Smaller scales were later introduced by John C. Hele, and also by William Whiteley in the Hope-Jones organs. The limit of smallness was reached when a viol was placed in the choir organ at Worcester Cathedral with the CC (8 ft.) pipe measuring only 1-1/16 in. in diameter. The Hele viol measured 1½ in. at CC, the tenor C pipe being 1 in. Such small scaling is now regarded as absurd, the tone being much too "wiry" and closely resembling that of the pressure harmonium free reed. The limit is now fixed at 2 in. for the 8 ft. pipe, while at the other end of the scale a diameter of 4 in. is considered the maximum. The relative scaling varies from half on the eighteenth to half on the twenty-fourth according to the absolute scale chosen at CC or tenor C. The larger scales halve on the eighteenth or twentieth, while the smaller scales halve on the twenty-fourth. I give the diameters of the C's for seven different grades of scaling, as follows:—

1.	CC, 4 in.	Tenor C, 2⅜ in.	Mid C, 1½ in.	Treb C,. 15/16 in.
2.	CC, 3⅛ in.	Tenor C, 2 in.	Mid C, 1-3/16 in.	Treb. C, ⅞ in.
3.	CC, 3-1/16 in.	Tenor C, 1⅞ in.	Mid C, 1⅛ in.	Treb. C, ¾ in.
4.	CC, 3 in.	Tenor C, 1¾ in.	Mid C, 1-1/16 in.	Treb. C, 11/16 in.
5.	CC, 2¾ in.	Tenor C, 1⅝ in.	Mid C, 1 in.	Treb. C, ⅝ in.
6.	CC, 2½ in.	Tenor C, 1½ in.	Mid C, 15/16 in.	Treb. C, 9/16 in.
7.	CC, 2 in.	Tenor C, 1⅜ in.	Mid C, 13/16 in.	Treb. C, ½ in.

Nos. 1 and 2 are "violoncello" scales. Nos. 3 and 4 are "viola" scales, and Nos. 5, 6 and 7 are "viole d'orchestre" scales. I am not in favour of the name "viole d'orchestre" which gives the case away completely: this direct reference to the orchestral instrument is manifestly unjustifiable. I would suggest the two names of **violoncello** and **viola** as quite adequate for the purpose, and if smaller scaling than No. 6 is used, the stop might be called **aeoline.** Voicers differ as to the width of mouth employed for these viols: some favour a fifth mouth (as easier to voice): others a two-ninths mouth, and others a fourth. It depends on the type of tone desired. A fifth mouth is quite suitable for the CC octave: it is also suitable for a certain type of viol which is sometimes labelled "aeoline" or "salicional." But the two-ninths and fourth mouths are the best for real organ string quality. The height of mouth is usually a third to four-elevenths of the width. The treble pipes are the most difficult for the beginner to voice, being very liable to instability of speech. The roller-bridges are not usually carried up beyond treble E for scales No. 1 to 6: for No. 7 it would be necessary to use the rollers as far as treble A. The diameter of the roller is graded from ⅝ in. at CC to 3/32 in. at treble C. Thynne used to place the roller as far away from the mouth as was consistent with prompt speech: many examples that have come under my notice have the rollers too close to the mouth, the result being a "tight" tone lacking freedom and spaciousness. Sometimes one finds that the rollers are too fat: this has the same undesirable effect on the tone. It takes, however, the expert manipulator to fit the right size of roller in the right position.

The upper lip of all viol pipes is usually made as sharp as possible with a vertical bevel about 3/32 in. in height along the front edge of the lip. This bevel encourages the extreme upper harmonics (shown in the analysis). Mr. E. M. Skinner, the well-known American organ builder, claims that this sharpening of the upper lip of a flue pipe is detrimental to its quality, "especially so in respect to strings." This is a matter of opinion, and most voicers would disagree with the statement. It all depends on the way the lip is sharpened and whether the under-surface is left perfectly horizontal, as well as on the other voicing adjustments.* And even after all such operations have been correctly performed the type of chest supplying wind to the pipe has the last word. This latter point is dealt with later. To proceed with the technique of voicing—there must be no attempt to push the upper lip **in**: rather it should be pulled out with a view to promoting quick speech. The lower lip should also be pulled out to match, making a widish flue, though care must be taken to avoid too wide a flue. As regards the nicking, great care is necessary, and the beginner must at first feel his way by giving the languid **only** from twelve to fifteen incisions with a light touch of the nicker. The pipe should then be tested for speech to see whether it is free from the initial "spit" or "buzz" which all small-scaled pipes are liable to utter. If the "spit" has not been eliminated, the nicking should be very slightly deepened. A few nicks (say, six to the inch) on the edge of the lower lip may be added. A practised voicer knows exactly what to do. Whiteley used to cut away the ears above and below the roller-bridge making the ears a support for the roller only: this enabled him to place the latter closer to the mouth and leave more space for the outside air. I do not favour this method, and prefer Thynne's as above described. Since the formant frequencies are of great importance to the quality of a viol, there should be a sufficient percentage of pure tin in the metal of which the pipes are made, good spotted metal being quite suitable for all types.

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* Mr. Skinner states that he "cuts the lip square" without sharpening it. The UNDER-SURFACE of the lip-edge should always be square as in the case of a wood pipe. The actual dimension from back to front is another matter.

It is usual to slot all string-toned stops, the slot being instrumental in reinforcing certain higher harmonics. If the pipe is not slotted there is a certain "stiffness" (not to say hardness) in the quality which appears to be due to the small scaling and the roller-bridge in combination. The tone is "freer" when the slot is introduced, but is not by any means pure. In other words, slotting **reinforces the wrong harmonics** and introduces "peaks" in the harmonic chain. These peaks are doubtless smoothed out by enclosure in a swell box with the shutters closed, but re-appear as soon as the shutters are opened. Below tenor C (4 ft.) there is no objection to slotting: it is from tenor C up that slotting should be employed with the utmost caution. A more pleasing quality is obtainable if bells (inverted conical funnels) are fitted to the tops of the pipes, but the difficulty of tuning such pipes without handling them (and so heating them) would deter most builders from repeating the process. The only alternative left to us is the "compensator" and the "cowl," either of which imparts the desired harmonic development to the tone without the reinforcement of undesirable overtones. The viola in my organ at Stagsden is so treated.

It has frequently been stated that string-toned pipes speak best on heavy pressure. This is only partly true. Much depends on the type of soundboard or chest used. In all chests in which the pallet opens **against** the pressure of wind the wind is not able to flow uniformly in the direction of the foot-hole of the pipe but is subjected to "shock-waves" which adversely affect the speech of the pipe. An aerial shock-absorber effect is produced by introducing a groove or expansion chamber between the pallet-hole and the foot-hole, as in the old-fashioned slider chest; or, alternatively, the type of pallet introduced by Mr. H. W. Homer (see Plate XV) ensures the desired uniformity of wind-flow to the pipe, with the expansion chamber added. In any case, a viol pipe placed over the pallet-hole of a chest with pallets or valves opening against the wind and deprived of the intermediate air pressure chamber is severely handicapped. Heavy pressure in such conditions is admittedly a help to the voicer, because the pipe always makes "first speech" on the initial blast of wind admitted to the foot by the pallet. With the wind flowing at sufficient pressure and velocity to start up the vortex system, the mature note follows at a speed which gives the impression of continuity of speech. But a formant is launched which may or may not prove detrimental to quality according to the scale and thickness of the pipe. It is therefore safe to say that viols should stand on suitably designed chests, and that wind pressures need not exceed 5 in. for normal results. At St. George's, Kidderminster, I placed a viola and its celeste in the swell organ voiced on this pressure of 5 in., the scale being that of No. 5 from CC to middle C and increased from that point to that of No. 4. The pipes have slots (a fifth of the pipe's diameter), fourth mouths cut up a third of the width, and stand on a slider soundboard (with the usual bars and grooves). Here is an instance where the slotted pipe is admissible, since the church is extremely resonant, and such buildings allow the voicer and designer to embark on a bolder treatment than would be desirable for the average type of building.

When height is a consideration, as may be the case in a swell box or a chamber organ, the longer pipes of viols and similar stops can be shortened by being "mitred." The straight portion of the pipe-body is taken to a distance not less than half the speaking length and then turned at right angles for the rest of the length; or else turned at right angles so that the horizontal portion is quite short, only a few inches long, and then again turned at right angles in parallel with the pipe-body (i.e. vertical again). In the latter case, the open end of the pipe faces the floor or soundboard and comes near to the mouth. This is called "double-mitreing." Care has to be taken to see that the open end is not too close to the mouth. Another method is that introduced by William Haskell, as shown in Fig. 6, the re-entrant tube being placed over the top of the pipe (whether the latter be a reed or a flue pipe).

Viols can be introduced on the manual in 16 ft., 8 ft. and 4 ft. pitch, but the complete family is not usually provided except in large organs. The viol mixture is described in Chapter VII. The lowest octave of the 16 ft. viol, or **violone** (sometimes labelled **violon d'orchestre**) may be scaled in accordance with Nos. 1 to 6, that is, from 7 in. down to 4 in. at CCC, with a fifth mouth. The top octave of the 4 ft. rank is given a larger scale in relation to the preceding octave, and in any case a scale smaller than that of No. 5 is not recommended, with the top octave increased to the scale of No. 4 or No. 5. This rank is labelled **violin**, **violette**, **violine d'orchestre**, or **gambette.** In the organ at Stagsden I have an example labelled **salicet.**

In America the larger scaled viol is often called **gamba** or **fugara,** though the latter name is in most specifications reserved for the 4 ft. stop and is of rather horny quality owing to its somewhat large scale with slotting. The name **gamba** was commonly used in this country in the Victorian period, but is hardly ever seen in present-day specifications.

Reference may here be made to a special form of string-toned pipe illustrated in Plate I and called "stenthorn." It has an inverted conical body (like the dolce), and is slotted at the top. The first model pipes of this stop were made by M. Talon under the direction of Professor G. Bédart. Mr. Frederick C. Mayer, organist of the Cadet Chapel at West Point, U.S.A., asked me to voice the stenthorn which is now in his organ (in the swell) to the following scale: tenor C (4 ft.) 2¾ in. at mouth, 3⅛ in. at top: middle C, 1¾ in. at mouth, 2¼ in. at top; and treble C, 1⅛ in. at mouth, 1-7/16 in. at top. The mouths are a fourth width, cut up a third of their width, and there are no rollers or beards. The wind pressure is 5 in. The quality of tone is more horny than stringy, but there is a powerful chord of harmonics accompanying a strong fundamental: it is rather difficult to say to what category the stop belongs, whether diapason or string, since I possess no harmonic analysis of its tone. It would appear to be a cross between diapason and string, having the strong fundamental of the former combined with the well developed overtones of the latter. I do not know of any other complete specimen of the stenthorn.

The **keraulophon** was a favourite Victorian quasi-string stop invented by Gray and Davison. The peculiarity consisted of a small circular hole made in the top portion of the cylindrical pipe where the slot is usually cut, the bottom end of the hole being continued down the pipe by means of a very narrow vertical slot which later was covered by a tuning slide. I have heard many specimens, none of which have ever struck me as exhibiting any special virtue. In practically every case the quality of tone is appreciably improved by covering up the hole and slot. The name "keraulophon" means "horn-flute tone" and is a most inapt description of the hybrid string quality actually produced. The slotted salicional is far preferable if it is desired to introduce this particular kind of tone in an organ.

Miniature versions of the viol in which the harmonic content is reduced without displacing it from its string category are represented by such stops as the **salicional,** **echo gamba**, **viole sourdine** or **muted viol**, **sylvestrina**, and **aeoline.**

The **salicional** is a name applied to several types of soft string tone, from the Hele "salicional" of diminutive scale to the Lewis "salicional" of diapason tone mentioned in the previous chapter. Most often it is a rather stringy dulciana, scaled one or two pipes smaller than the dulciana and slotted. The **echo gamba** would have yet a smaller scale and be fitted with rollers. The **viole sourdine** was introduced by Thynne and given the No. 4 scale with slots and rollers: its mouth was a fifth of the circumference in width, and the foot-hole was quite small. The pioneer example is still to be found in the Grove Organ at Tewkesbury Abbey. Whiteley developed a more ethereal-toned version for Hope-Jones under the name of **muted viol.** This had conical tubes as shown in Plate I, the scale being only 1¼ in. at the mouth line and ⅝ in. at the top for the 8 ft. pipe, and 1 in. at the mouth at tenor C (4 ft.). The mouth was only a sixth of the circumference in width, and the voicing was the same as for the viole d'orchestre of this scale. Whiteley in a letter to me described it as an "echo viole · d'orchestre." The **sylvestrina** is a modern Willis stop, also conical with a taper of 4 : 1, the scale at CC (8 ft.) being 3-9/16 in. at the mouth line, and 2 in. at tenor C (4 ft.). The mouth is a fifth, cut up four-elevenths of the width and slightly arched. In the CC octave the pipes are all the same scale. The tone is perhaps best described as that of a "gemshorn dulciana." The **aeoline** is in reality a small-scaled viol with a narrow mouth (e.g. a fifth of the circumference) cut up as low as possible and lightly blown. It is rather more stringy than the viole sourdine and is to all intents and purposes an echo gamba.

String tone can also be produced from wood pipes, as Schulze, Pendlebury and Whiteley have demonstrated, and there are few builders in this country who have not wood string basses to their credit. One reason for Schulze's preference for wood pipes for the basses of his diapasons was his objection to front speaking pipes of metal. At Armley there is only one metal flue bass in the whole organ, all the rest are of wood. The most striking example of Schulze's work in the category of string tone is at Hindley. The scale of the **contra viola,** 16 ft. on the great manual of this organ is 6¼ in. by 5 in. at the 16 ft. pipe, the mouth being 1 in. high and fitted with a wooden bridge. The famous **cello,** 8 ft. at Armley is 3⅜ in. square at the 8 ft. pipe. The **violin** of Thomas Pendlebury is also equally famous. The scale at CC (8 ft.) is 2 in. square, at tenor C (4 ft.) 1-3/16 in. square, at middle C (2 ft.) ¾ in. square, and at treble C (1 ft.) ½ in. square. The cap and block arrangement is shown at H in Plate II, the block edge being notched. Compare this formation with Schulze's at E, F, and G, where the cap and block are set at the same level and there is no nicking. The **echo oboe** in the echo division at Armley is also a wood stop of rather curious tone, more reedlike than stringy.

If asked to state the difference between the merits of wood and metal for the production of string tone I should unhesitatingly reply that for pipes **above** middle C (2 ft.) metal is to be preferred, and that below that note either wood or metal is equally good. It is indeed largely a matter of taste as to which material is employed by a builder. The **only** difference between wood and metal seems to lie in the weight of tone given by the wood pipe. There is a higher percentage of fundamental in the harmonic content of a wooden viol bass which commends it as a pedal register: otherwise, a well designed and voiced metal or zinc pipe is capable of equally good results. Above middle C the wood string pipe is apt to give a certain coarseness of tone which is more noticeable in the playing of chords than of single notes. For this reason wood viols on the manual are not popular, apart from the extra labour and time entailed in making and voicing such pipes.

A brief discussion on the subject of **celeste** effects in general will conclude this chapter. The purist has no use for this special effect, produced by two separate sets of flue pipes, one in tune, the other made slightly sharp or flat in order to beat with its partner. This question of "being in tune or out of tune" is by no means the simple, straightforward matter that musicians seem to imagine. It is only within recent years that the oscillograph has discovered that the harmonics of an organ pipe (or of an orchestral instrument) are not in exact tune with the fundamental. If they are forced by improper treatment (by the voicer in the case of organ pipes or by the player in the case of an orchestral instrument) to a degree of out-of-tuneness which is offensively noticeable, the result is a noise rather than a musical note. It is the human ear and the human aesthetic sense (to which the ear is the door) that alone determines whether a sound or a combination of sounds is pleasing or not. Robertson, in his treatise on organ building, condemns the celeste as "a gross libel on the harmony of the spheres": in other words, he objects to the association of the term "celestial voices" (**voix celestes**) with a perfect world of sweet sounds. Those who adduce such an argument forget that the real purpose of the celeste effect is to lend vivacity and movement to the tone in precisely the same way as vivacity and movement is imparted to the strings of the orchestra by the various violins, violas and cellos not being in exact tune with each other. The whole effect may be described as a "pulsating harmony" or a "harmony of pulsation." The contention of the purist, if carried to its logical terminus, would deprive man of music altogether, and I gravely doubt whether absolute freedom from out-of-tuneness can ever be compatible with musical perfection. By "absolute freedom" I mean the complete absence of any dissonance at any time or in any part of the structure of the whole. The unequal temperament system of tuning a keyboard instrument gave us a strictly limited set of keys for the composition of music, while the equal tempered scale gave us far more and made possible the immortal works of Bach (and all the other great composers). Yet equal temperament produced "beats" and dissonant intervals which the purists of those days were not slow to condemn as intolerable. Similarly, the celeste introduces a new effect in contrast to the statuesqueness of "pure organ tone." It is thus justified. But it must be artistically designed and produced as well as used.

There are four main types of celeste. We may select a couple of dulciana stops, and tune one of them slightly sharp or slightly flat in relation to the other, making a **vox angelica.** It really does not matter whether the out-of-tune rank is tuned sharp or flat. Or we may take a couple of viols and treat them similarly to form a **violes celestes**; or a couple of soft-toned flutes—an **unda maris**; or a couple of miniature string stops, such as the salicional, sylvestrina, sourdine or aeoline—a **voix celestes.** There are two rules which the experience of organ builders has formulated in the treatment and design of the celeste. The first is that the two partner ranks should not be too dissimilar in type and timbre; and the second is that the rate of pulsation (i.e. the degree of sharpness or flatness of the out-of-tune rank) depends on the precise harmonic development of the two stops. Thus, the first rule is broken if we try to form a celeste from the combination of a dulciana with a viol, while the second rule is broken if we tune the dulciana celeste to too quick a beat or the viol celeste to too slow a beat. Speaking generally, the beats should not be so slow as to defeat the object for which the celeste was introduced, nor so quick as to produce a wobbling effect rather than a wave. There are other rules which the designer would do well to observe even if they are of less importance. One is that the two ranks should be so planted relatively to one another as to preclude any interference due to "stationary waves." The effect of the latter phenomenon is to exaggerate the pulsation of certain notes in the series, the waves surging to a hysterical peak and as suddenly dying down instead of executing a gentle up and down motion. To avoid this unpleasant effect it is desirable to place the two ranks at some distance from one another on the soundboard. Another point is the desirability of placing both ranks on the same pressure of wind; while another factor contributing to the success of a celeste is the way in which tuning is carried out. Some builders ''lay the bearings'' on both ranks in turn and tune the ''celeste rank'' in octaves up and down from the middle octave. The result is that the treble notes of the celeste beat too quickly and the lower notes too slowly. The late Edwin H. Lemare pointed this out many years ago and used to recommend tuners to set the beat-rate of each note separately without reference to the temperament: that is, if one drew the out-of-tune rank separately and played chords on it alone the result would be bad owing to the absence of any definite system of tuning—the treble and tenor octaves would be out of tune with the middle octave. This, however, would not matter since the out-of-tune rank would never be used by itself but only with its partner rank. My own method is to tune each note from middle C to treble C so as to give a uniform rate of wave at the speed best suited to the harmonic content of the two stops in question: I then play a succession of chords in that octave in order to test the effect. If satisfied with the result, I proceed to tune each note from middle C sharp up, gradually increasing the rate of beat till G above treble C is reached; after which I maintain that rate to the top note. The tenor octave is then tuned to a slightly quicker beat than that chosen for middle C, each note in this octave being given a uniform rate. The majority of celestes stop at tenor C (4 ft.), though there are some examples that go down to CC. There are also octave celestes in the larger organs. It is more usual, however, to produce the full celeste effect by means of octave couplers. Enclosure in a swell box is imperative: the only effective celestes outside a swell box that I know of are those which occur in very resonant buildings.

A celeste effect consisting of three unison ranks of pipes occurs in some organs. One of the ranks is in tune to the pitch of the organ, while the other two are sharp and flat respectively, beating on either side of the in-tune rank. The result does not justify the extra cost, space and labour involved, and the three-rank celeste is now obsolete. Casson used to recommend tuning a two-rank celeste so that neither of the ranks was in tune to the pitch of the organ; but this means depriving the organist of one of the ranks for separate use or for combination with other in-tune stops.

CHAPTER IV

The Flutes

FLUTE tone to an organ builder signifies a paucity of harmonics above the fundamental. A "fluty tone" is a dull tone, though not dull in the sense of uninteresting. A flute stop may be extremely beautiful, and it is not true to say that it palls on the ear because of its lack of the higher harmonics. I know of an organist who derives the acme of aesthetic enjoyment from improvising on a Walker waldflute. He will sit for a whole hour at his organ playing on this one stop. Is he guilty of a debased taste? Certainly not. A well-voiced organ flute can produce a ravishing quality of tone of which one does not quickly tire. Yet I do not think there is an organist who would be content with an all-flute organ for all time. It is true that there are musicians, like the late Sir Walford Davies, who have a personal preference for the kind of tone which by others would be regarded as ultra-refined. As we have already observed, the French like brilliance and *éclat* and plenty of it: the Anglo-Saxon taste lies more in the direction of massive solidity and dignity. But nature has provided harmonics, and presumably they have been provided for our benefit. Variety is the spice of life, and contrasts play a great part in heightening human emotion. So we appreciate the chaste refinement of the flute all the more for the scintillating richness of the string or the noble dignity of the diapason.

If an organ flue-pipe on analysis of its tonal constituents is found to produce a strong fundamental, octave and twelfth (the first three harmonics) with a definite weakening of the harmonics that follow, we are justified in stating that it is a flute. The harmonics may be present up to the tenth, but after the fourth the decrement is pronounced. It may be asked whether a very pure-toned reed pipe such as the French horn would not fit equally well into this category. The answer is No. All reed pipes give at least the first six harmonics at more or less equal amplitudes, a feat of which the flute is quite incapable. But we need not waste time arguing over the matter, for our ears can tell us at once whether we are listening to a flute pipe or not.

Flutes are classifiable into two main divisions, (1) the open flute and (2) the stopped flute. There is also the harmonic flute, open and stopped, and there is the partially stopped flute: these latter varieties are sub-divisions which we shall consider in their turn.

1. **Open Flutes.** These comprise all those pipes which are open at the top and of normal length. I propose to consider in this section only the tenor C stop, that is, flutes from the 4 ft. pipe to the top pipe. There is a good reason for this, since many open flute stops have stopped basses, though it is the opinion of the majority of critics that the open pipes should be continued down to CC. Further, the quality of the flute possesses its main significance in the tenor C to top compass of the stop, and the lower notes are generally regarded as a separate unit as far as design is concerned. As already stated in the chapter on the Diapason, organ builders commonly speak of "matching the bottom octave of pipes to the tenor C note" and of "successfully concealing the break" between the BB and tenor C

pipes. In the case of stops giving a rich chord of harmonics such as the viol and the reed this matching problem does not arise, since the continuity of the stop is achieved by a correct scaling of the pipes throughout the complete compass; but the diapason and the flute do not respond so obligingly to this treatment, and the bass notes require special treatment in order that the stop as a whole may be a success. Unlike the diapason, the flute tends to lose its vitality in the lowest octave below 4 ft., and I shall add a short paragraph on this subject at the conclusion of this chapter.

The metal flute will be considered first. This is in reality a diapason pipe with its mouth cut up till flute tone is produced. Pipe-makers often call this type of flute a "tub," by which nickname they mean a rather large-scaled open metal pipe of normal speaking length voiced to give a prominent fundamental with very little harmonic development. The mouth is not only well cut up but is often arched—presumably to prevent windiness—and the upper lip is pulled somewhat outward to ensure purity of tone and to produce a certain characteristic "bloom" obtainable in no other way. The degree of cut up depends on the scale of the pipe and the width of the mouth. A small scale requires a higher cut up than a large one, and a narrow mouth also requires a higher cut up than a wide one. So the voicer has to use his discretion. Generally speaking, the best results are obtained from moderate scales and narrow mouths. By a moderate scale I mean a scale of the order of 3 in. at the 4 ft. pipe, and by a narrow mouth I mean a width not exceeding two-ninths of the circumference. It is usual to cut the mouth up to two-fifths of its width and then to increase the height (on the given wind pressure) till all trace of diapason tone is eliminated. I do not recommend a smaller scale than 2¼ in. at the 4 ft. pipe, since the mouth would have to be cut up too high or made too wide with a narrower pipe. The nicking should be the same as for the diapason, and plain metal is quite satisfactory provided it is sufficiently stout.

It is possible to give the open metal flute pipe a conical body, tapering from the mouth to the top in the ratio of 3 to 2 (the best ratio). This is usually called a "flûte conique" and is not a gemshorn or a spitzflöte (see Chapter II). I remember my maiden effort at voicing a flûte conique for the organ in the Chapel of the Royal Orphanage School at Wanstead (Essex), and having some trouble with the pipes from 1 ft. up. These particular pipes objected to their mouths being cut up for flute tone and voiced their resentment by "spitting and coughing." A larger scale would have overcome the difficulty, but I preferred to substitute cylindrical pipes for the conical from this point.

The inverted conical pipe (see the **dolce** in Plate I) is equally capable of giving flute tone if the mouth is cut up for this purpose, but I have never encountered an example other than the soft-toned **dolce.** This latter pipe is in reality a miniature open flute or flute-toned dulciana. It appears to have been introduced to us in this country by Snetzler in 1741 at Chesterfield Parish Church, though it was Schulze who popularised it in the sixties. The ratio of diameter at the top of the pipe to that at the mouth end is as 3:2, the tenor C (4 ft.) pipe measuring 1¾ in. to 2¼ in. at the wider portion. The mouth is usually two-ninths wide, or a fourth, as decided by the voicer, and cut up two-sevenths of the width at least. The **corno flute** of Herbert Norman was a cylindrical pipe fitted with an inverted languid and voiced to give a soft fluty tone for the purpose of providing a neutral-tinted accompaniment to solo stops on another manual. Its scale was 1½ in. at middle C (2 ft.), the mouth being a fifth wide. The **fernflöte** and the **zartflöte** of Schulze was composed of small-scaled gemshorn pipes (the zartflöte being usually of 4 ft. pitch) voiced to produce a soft, delicate-toned flute.

The flute pipe of wood has always been very popular with builders. At first the wood pipe was stopped (and we shall consider the stopped pipe later), and J. C. Bishop found that by removing the stopper from a large scaled stopped diapason pipe he was able to produce a soft, round, full, velvety flute note without cutting up the mouth. This was the Bishop **clarabella,** which usually consisted of open wood pipes from middle C to top note and was continued downward in stopped wood pipes. A very common scale was 1⅞ in. by 1⅝ in. at middle C (2 ft.). The block and cap were shaped as at C in Plate II, and the feet were well plugged to keep down the pressure and so prevent the low-mouthed pipe from overblowing. Father Willis's **clarabel flute** was cut up higher and possessed a unique quality. Schulze introduced the **hohlflöte** with the cap and block as shown at A in Plate II: this type of flue promotes the first five harmonics with emphasis on the second and fifth, and the quality of the note is therefore "sweeter" and more "open." Actually, what Schulze did was to cut up a wood diapason pipe and convert it into a flute. There is a fine example at St. Mary's, Tyne Dock, on the great manual. This kind of pipe can be made either square as at Tyne Dock or rectangular, and if the latter shape is chosen the mouth may be on either the wide or the narrow plank. Mr. Binns favoured the wide side for the mouth: it was Schulze, again, who introduced this variety in his 1851 Exhibition organ. At Doncaster, and again at Armley and at Hindley, Schulze introduced the triangular pattern on the great manual (in all three instruments), the scale at the 4 ft. pipe being 2⅞ in. by 2¾ in. with the mouth approximately 1½ in. high. Modern builders prefer the inverted upper lip for this type of pipe, as illustrated at B in Plate II. The famous **waldflute** of Walker has this formation of lip, the pipe in this instance being rectangular in shape with the mouth on the narrow plank. It may interest the reader to know the actual dimensions of the Walker waldflute upon which my organist friend, mentioned earlier in this chapter, used to improvise with such rapture and for such prolonged periods. Middle C (2 ft.)—the first open pipe—measured 1⅝ in. by 1½ in., cut up ⅝ in. with 11 nicks on both block **and cap**: treble C (1 ft.), 1 in. by ⅞ in., cut up 5/16 in., with 10 nicks on block and cap: 6 in. C, 11/16 in. by 9/16 in., cut up ¼ in., with 9 nicks on block and cap. Wind pressure, 3¼ in. A truly beautiful stop. There are equally fine examples in hundreds of Walker organs, and it is impossible to excel them. One of the secrets of the lovely quality of this open flute lies in the manner in which the notching is done on the inside of the cap. No written or spoken word can give this secret away: it must be seen to be appreciated. And I am speaking the truth when I state that in the whole of my experience, extending back to 1895, I have never once encountered an organ stop made and voiced by any other builder than Walker which could honestly be said to resemble the "Walker waldflute." I essayed a copy myself at Willesden Green Baptist Church (London), but only succeeded in producing an inverted mouth waldflöte of my own! Father Willis was fond of putting inverted mouth hohlflötes in his choir organs, and very beautiful they were. In America the inverted mouth open flute corresponding to the English hohlflöte and waldflöte is called the **melodia.** As regards the physics of the inverted lip I have observed that this particular formation encourages the second harmonic as well as certain of the higher harmonics. These higher harmonics are only too ready to sing out at the onset of speech: for which reason the nicking has to be rather drastically applied. I know of no organ flue pipe in which the nicking process is more important as a voicing expedient, and I know of numbers of examples in which the nicking has been improperly applied with fatal results. The **only** way a novice can ascertain the correct depth and width of the notch is to get hold of a model pipe and copy the nicking exactly, or, failing the model, to experiment with a series of caps, trying each one against the block (which latter may be moderately notched) till the right tone emerges from the pipe. The inverted lip has been much utilised by the late William Haskell of America for the production of his special "labial reed" tones, but a description of these is reserved for a later chapter.

A special kind of open wood flute is the **tibia.** Hope-Jones introduced the "tibia plena," a large-scaled clarabella with leathered lip; but in reality it was only the "open diapason" of wood that was found on so many English pedal organs carried up in 8 ft. and 4 ft. pitch on the manual, and leathered. Its tone was hardly pleasing, carrying foundational flutiness to an extreme and upsetting any combination of stops with which it was blended. "Take that hooter away" was the agonised appeal of a well-known organist who had had to bear with it as the only 8 ft. flute stop on his great manual. It was transferred to the solo manual and replaced on the great manual by a normal-toned flute.

The **flauto amabile** or **flute d'amour** is a miniature waldflöte, having inverted mouths on the narrow plank, with a scale of the order of 1⅝ in. by 1¼ in. for the 2 ft. pipe. It may also be made triangular, and the Willis **flute triangulaire** is a beautiful example of the type. The **suabe flute** is a 4 ft. flute and usually an octave waldflöte with inverted mouth. It was introduced by William Hill, and an exceptionally fine example of it is to be found in the unenclosed choir of the Hill organ at Great Brickhill Church (near Bletchley, Bucks.), the scale at 2 ft. C being 1¾ in. by 1⅜ in.

A flue pipe may have two mouths either opposite each other or on adjacent planks. The **doppelflöte** is an example of such a pipe. It is made of wood and may be either open or stopped. The object of the double mouth is to thicken the tone and increase the fundamental. The **seraphonflöte** of Weigle (of Stuttgart) had its two mouths on the adjacent sides of the open pipe. Although this section deals with the open flute, it is the stopped doppelflöte that gives the most satisfactory results. But the two mouths require adequate space for efficient speech, and such a demand does not tend to make the double-mouthed pipe popular with organ builders. If the two mouths are placed at slightly different levels they may produce a wavering note—a defect rather than a virtue.

2. The **stopped pipe,** giving the odd series of harmonics only, has already been mentioned, and here it is only necssary to give the names and particulars of the various types. The oldest is the original wooden large scaled pipe completely stopped at the top with a low mouth and a cap and block formation as shown at C in Plate II. This kind of stop is capable of producing a beautiful tone all its own, though practically every example of my acquaintance exhibits an irregularity in its successive notes which might almost be deemed characteristic. One does not— strange to confess—seem to mind the little odd-harmonic excrescences that leap out from a note here and there as one's fingers traverse the keys: they lend a peculiar charm to the whole and relieve the dull, dead monotony of the perfectly "straight-line' regularity of the other flutes in the organ. I would not have an organ bereft of one of these old-world stopped diapasons. The old builders used to leave the bass octave of pipes in sorry condition, both tonally and structurally. The pipes invariably "coughed" their note, sounding the twelfth above the fundamental (the third harmonic) before the real note; and the stoppers were frequently loose, so that the note was weak and windy. In any case it is much

better to employ the German type of stopped wood bass for all stopped flutes, as shown in Plate II A. The English type of wood **stopped diapason** (not really a diapason, of course, but a flute) had an average scaling of 4 in. by 3 in. at CC (8 ft.), 2¼in. by 1¾ in. at tenor C (4 ft.), 1-5/16 in. by 1-1/16 in. at middle C (2 ft.), and ⅞ in. by ⅝ in. at treble C (1 ft.). The mouth would be cut up about a third of its width and would be on the narrow plank. The pressure of wind must be low, not exceeding 3 in., if the old-world tone is to be preserved. A singularly beautiful example by Hill on 2⅜ in. pressure occurs in the great organ at St. Mary's, Primrose Hill, London: the middle C pipe measures 1½ in. by 1⅛ in.

The German type, known as **gedackt** or **gedeckt,** has its block and cap formed as at A in Plate II, which formation favours the fifth harmonic or tierce. Thus, the tendency, so characteristic of the English type, to overblow to the twelfth is corrected. The quality is also brighter, as one would expect from the increase of harmonics in the odd series. At the same time, the tone of the German gedackt if made of wood, lacks the charm of its English brother, and curiously enough is only able to capture that charm when made of metal. Even so, the quality is quite different from that of the stopped diapason. Schulze "brought the house down" with his **lieblich gedackt** of metal when he sent his small two-manual organ to the Hyde Park Exhibition in 1851. Organists visiting the Exhibition were tremendously struck by the "new tone," not least the great Dr. E. J. Hopkins who got Schulze to put one of these stops in his Temple Church organ. Schulze used plain cork stoppers, while Father Willis preferred to use wooden stoppers for his liebliches with a hole bored through the centre (see Plate II). An average scale would be 1-3/16 in. at middle C (2 ft.) with a mouth ½ in. high. Lewis was fond of introducing a complete family of liebliches from 16 ft. to 2 ft. in his choir organs, the 2 ft. stop being stopped right up to the top note. I quote two examples: St. Peter's, Eaton Square, London, and Ripon Cathedral. The upper lips of the gedackt are not "flatted." J. C. Bishop produced a wooden imitation of the lieblich gedackt which he labelled "stopped metallic": the pipes were cylindrical, bored out of solid wood. The **rohrflöte,** much used by Snetzler, was a metal pipe fitted with a metal cap in place of the wooden stopper or tompion, while from the centre of the cap there projected a narrow tube or "chimney," the diameter of the chimney being from a third to a sixth of the diameter of the pipe and its length a quarter of the pipe's speaking length. The chimney can be inverted so that it is completely concealed within the pipe-body. It has been claimed that the lieblich gedackt or gedackt of larger scale fitted with perforated wooden stoppers gives the same quality as the rohrflöte; but it does not, for the simple reason that the metal capping of the latter introduces a distinct formant. The French builders have a great liking for the large-scaled metal pipe fitted with "canister stoppers," which are sliding capped cylinders of thick metal lined inside with paper to make an airtight fit on the top of the pipe. This is the **cor de nuit** (nighthorn). With the chimney added it would be called a **flute à cheminee.** (See Fig. 5, E and F.) The German **nachthorn** is similarly constructed with a canister top. The **koppelflöte** is a "baroque" stop much used by the old German builders of the fifteenth century onwards. Mr. G. Donald Harrison in America and Mr. Henry Willis in this country have both reintroduced this stop into the modern organ. Its formation is shown in Fig. 5D. I am grateful to Mr. Willis for particulars of its construction and voicing. As shown in the drawing the upper end of the pipe-body is fitted with a canister stopper consisting of a cylindrical portion which is once and a half the diameter of the pipe in length, and of a conical portion which is twice the diameter of the pipe in length. The top of the conical portion is capped, but has a small hole in the centre of the cap which is a fifth of the pipe's diameter in size. The pipes should be made of thin metal, preferably tin. "Knife-cut" nicking is essential to a successful result—in fact, the nicking is a very critical feature of the voicing. The scales at 4 ft. C are (a) 2-11/16 in. for the 8 ft. stop, (b) 2¼ in. for the 4 ft. stop (perhaps the most frequently used), and (c) 1⅞ in. for the 2 ft. stop. All the pipes are "eared," and the mouths are fourth width cut up half the width or to the correct height to suit the wind pressure and the power desired. There was a beautiful example by Mr. Willis at the Colston Hall, Bristol, which was destroyed in the fire of 1944.

An interesting type of stopped flute is the **tibia clausa or tibia minor,** the former a Hope-Jones product and the latter introduced by John Compton. The tibia clausa of Hope-Jones had wooden pipes, scaled 2⅝ in. by 1¾ in. at the 2 ft. note, and leathered. The Compton tibia minor is a metal stop, about 2⅛ in. at middle C (2 ft.) with a very narrow mouth (a sixth) and **lightly blown.** There can be no doubt as to the beauty of such a stop so treated.

3. We now come to the **harmonic flute,** open and stopped, wood and metal.

The open harmonic flute may be made of wood or metal, but is rarely of wood in the modern organ. The metal pipe will therefore be described. It is of double length—the very opposite of the stopped pipe which is half the normal length of an open pipe—and in order to facilitate its overblowing to the octave above the fundamental, a small hole is pierced in the "middle" of the body: the mouth is also treated so as to encourage overblowing, and the foot-hole adjusted to the wind pressure. The object of the voicer is to imitate the orchestral flute with its characteristic "piff" and its harmonic development. In all probability Schulze achieved the closest imitation in his cylindrical wood pipes in the Doncaster organ, labelled **flauto traverso** (see Chapter VIII), but many fine examples in metal are to be found in hundreds of organs. There are several varieties. The scaling, size of mouth, position of node-hole, and the quantity of wind supplied to the foot—these factors profoundly affect the quality and power of the pipe. Generally speaking, the power is determined by the scale, the cut up and the pressure of wind; the quality is determined by the scale, the size of the mouth and the size and position of the node-hole. A small-scaled pipe produces the flauto traverso: larger scales produce the "harmonic flute." The placing of the node-hole is of some importance: it is often bored at a distance of "seven-sixteenths up the pipe," that is, a little below the actual centre of the speaking length. I have referred to the "piff" of the orchestral instrument, and it is the node-hole that is responsible for this effect. If I take a pipe voiced to give harmonic flute tone and bore the hole at the exact centre of the body, and then blow the pipe very gently with my mouth, I shall find that the unison note will be sounded—a very feeble hum note a minor seventh lower than the note I want. If I blow harder I get the minor seventh above—the note I want—and possibly I may also hear the anticipatory hum note preceding the mature note of the flute. I can make sure of this anticipatory hum note or "piff" by adjusting the lips or keeping the mouth low in relation to the wind pressure or the size of foot-hole—in fact, a sure and certain way to eliminate the "piff" is to reduce the foot-hole till all trace of the anticipatory note has gone. But supposing I bore the node-hole at a spot a trifle **below** the centre-point? Then I get the major seventh for the hum note, and this is the usual spot. Personally I dislike the major seventh intensely and studiously avoid this particular spot for piercing my holes: I greatly prefer the major sixth, and select a spot **nine-sixteenths** up the pipe, just **above** the centre.

There is this additional advantage that the pipe can be blown much harder without overblowing to the third harmonic (the twelfth) and in consequence the mouth can be kept rather lower, an important factor contributing to good quality. The normal size of the hole is 3/32 in., and this can be enlarged if desired or else a couple of small (say 1/16 in.) holes can be bored: this latter method is useful if one wants to feel one's way in search for the optimum size of node-hole.

As regards the best scales for the harmonic flute, the voicer must first decide whether he wishes to obtain the orchestral effect of the "concert flute" (designed primarily for solo use) or more normal tone for use in combination with other stops. In the former case it is best to adopt a moderate scale with a low mouth, the exact height of the mouth being relative to the pressure applied and the power required. For this purpose I can confidently recommend a scale of 2⅝ to 3 in. for the 4 ft. length pipe speaking middle C, the treble C note being obtained from a 2 ft. pipe 1⅝ to 1¾ in. in diameter. The mouth may be a fourth or two-ninths of the circumference in width and cut up tentatively a third of the width, the main objective being to prevent the pipe from speaking its twelfth before settling on to its proper note. If it does this, the cut up should be increased or else the foot-hole reduced; but the latter operation also reduces the power of the note, so that if it is desired to maintain the original strength the mouth must be increased in height. A very important point in the treatment of orchestral-toned harmonic flutes is the provision of ears right up to the top note. I learned this from a study of Walker's fine examples. What wonderful flutes in both wood and metal this firm has turned out! Though it has no monopoly of them; for there are many splendid examples in the organs by Hill, Willis, Norman and Beard, Harrison and Harrison, Rushworth and Dreaper, Compton, Binns, and other builders too numerous to mention. This combinational harmonic flute (in 8 ft. and 4 ft. pitches) is voiced to give a very pure tone with a firm articulation, and is therefore cut up higher than its orchestral-toned brother. Often one finds an arched upper lip and a fifth mouth. A very common scale is 1⅜ in. at middle C for the 4 ft. stop; and the pipes below this note are usually of normal length, that is, non-harmonic or "tubs." Lewis was very partial to the 8 ft. harmonic flute on the great manual in place of the more usual clarabel flute or hohlflöte, and the first harmonic pipe usually began at treble C—never below middle F.

The **flauto traverso** was mentioned above in reference to a stop made by Schulze of special construction; but the name is frequently used in conjunction with a small-scaled harmonic flute of metal in 4 ft. pitch and commonly found in the choir organ. It is a delicious-toned stop and much in request for the accompaniment of church music when it is desired to add brightness without shrillness to such unison stops as the stopped diapason, waldflöte, dulciana, salicional, etc. There is a beautiful example in the swell of the organ at St. John's Wood Chapel by Bishop, which I copied for my organ at Stagsden Church. A good scale is 1¼ in. at middle C (2 ft. length of pipe speaking 1 ft. note), ⅞ in. at treble C, ⅝ in. at the 6 in. C: mouth having a fifth or two-ninths width. The diameter of the first "tub" (i.e. the tenor B pipe, non-harmonic) is 1 in., with a two-ninths mouth cut up 11/32 in., while the C pipe below (2 ft. long) is 1¼ in. with the mouth cut up 7/16 in. Let it be noted that (a) the top lip is not flatted, (b) every pipe of the complete stop is eared, (c) the foot-holes are adjusted in size to the pressure of wind employed, and (d) the node-holes are pierced as for the larger scaled harmonic flute.

The stopped harmonic flute is usually called **zauberflöte**, a name introduced by Michell and Thynne in 1885 when they exhibited the fine organ now in

Tewkesbury Abbey (known as the "Grove Organ"). The pipes in this instance are stopped from tenor C up, being three times the length of a normal stopped pipe, and sound their twelfth. A small node-hole is pierced at a distance of nine-sixteenths up the pipe-body. From tenor C to E (five notes) the pipes are of wood: thence to top they are of metal. The scale at tenor C (4 ft. tone) is 2¾ in. by 2⅛ in., this pipe being 33½ in. long (measured from the top of the block). Middle C is 1-15/16 in., its length being 16¾ in. from the upper lip. The mouth is two-ninths in width and cut up a quarter of its width. A "harmonic rohrflöte" by Snetzler occurs in the organ at St. Margaret's, King's Lynn, under the name of **German flute.** Its scale at middle C is 1¾ in., and the pipes are fitted with the usual "chimneys." Fine examples of the harmonic stopped flute are made by Rushworth and Dreaper under the name of **flute bouchée harmonique.**

It should be obvious to the reader that when we speak of any given type of pipe we are entitled to visualise it as a member of a complete set of pipes all made in similar fashion. Thus, a stopped diapason may consist of pipes whose length ranges from 32 ft. to only half an inch. The same may be said of any class of pipe in theory, though in practice—as in the case of the harmonic flute—it may be found inadvisable to extend the series beyond a convenient limit. It is perfectly feasible to apply the pitch nomenclature of 32 ft., 16 ft., 8 ft., 4 ft., 2 ft., and 1 ft. to a stop name such as the diapason, stopped diapason, dulciana, gedackt, hohlflöte, waldflöte, etc., without altering the name of the stop itself. However, this is not accepted practice with organ builders in general: a 32 ft. stopped diapason is called a **sub-bourdon,** a 16 ft. stopped diapason is called a **bourdon,** a 4 ft. stopped diapason is called a **stopped flute** or a **nason,** a 2 ft. stopped diapason is called a **piccolo.** But a 2 ft. harmonic flute is also called a piccolo (sometimes a flautina), though properly it should be called a harmonic piccolo; while the 2 ft. lieblich gedackt is sometimes called a lieblich piccolo. The last-named is a bad mixture of German and Italian, and T. C. Lewis preferred to use the label, "lieblich gedackt, 2 ft." Again, the waldflöte is so named when of unison pitch: in 16 ft. pitch it is called **contra waldflöte** (as in some Walker organs where it occurs as a "double" on the great manual), while in 4 ft. pitch it is called a **suabe flute** or simply a flute, 4 ft. In the case of an extension or unit organ (see Chapter IX) where the complete family of pipes are planted on a single unit chest, the basic name of the stop so treated need not be changed or modified in any of the pitches employed, so that a hohlflöte consisting of 97 pipes from 16 ft. to 2 ft. can be divided into four sections labelled "hohlflöte, 16 ft., 8 ft., 4 ft., and 2 ft." And this leads me to the subject of the 16 ft. octave of the flute.

The 16 ft. stopped flute is, as we have stated, the **bourdon,** while the 16 ft. open flute is the **contra waldflöte** or the **contra hohlflöte.** On the pedal organ these names may be altered to **sub bass** for the bourdon and **open, 16 ft.** for the open flute. We are, however, now concerned with the manual stops only. It is not often that the manual double open flute is carried down to the bottom note in open pipes. It is more usual to find the open pipes taken down to middle C of the manual (speaking tenor C) and continued from that point in stopped pipes (i.e. as bourdons). Strictly speaking, therefore, the double flute is a stopped pipe in wood or metal. The scale varies between that which is suitable for the lieblich type and that which produces the full stopped pipe effect. The lieblich bourdon may measure 6 in. by 5 in. at the 16 ft. pipe with a mouth 4 in. high, though Schulze used a scale 5 in. by 3⅜ in. at Hindley. The full-scaled bourdon is mentioned in Chapter VI. A metal bourdon is best made of canister-capped tubes, with sliding stoppers for tuning purposes. The scale at 16 ft. C may be 5½ to 6 in.

Flute-toned manual doubles are very popular, and deservedly so. Schulze placed a bourdon on the great manual at Tyne Dock instead of the double open diapason. T. C. Lewis was very partial to the great organ bourdon. There is a reason for this. If we draw the following combination of stops on the great manual—stopped diapason, principal (4 ft.), twelfth, fifteenth—and play an octave lower, we shall be struck by the wonderful cohesion resulting, if the stops are not so ill-voiced and regulated as to make any combination impossible. This is tantamount to drawing bourdon, open diapason, quint and principal. The bourdon must be given the right treatment if it is to take its place in the chorus and not produce a "muddy" effect. Enclosed bourdons frequently err in this respect, the swell box in which the pipes are enclosed having a damping effect on their harmonic development. It is generally agreed that the tone of the manual bourdon should be "transparent": a small scale wood pipe or else a metal canister pipe answers the purpose best. Binns used to increase the power of his great bourdon treble register so as to counterbalance the thickening effect of the lower portion, but most voicers keep the power level throughout from tenor C up.

Another type of stopped double is the **quintaton.** This is a pipe, usually of metal with a canister stopper, encouraged to speak its twelfth as well as its fundamental. For this purpose it is fitted with a beard or bridge, the mouth being kept low so that the pipe may overblow readily. The quintaton is much favoured by certain builders for a quiet double on the choir manual: the twelfth robs the fundamental of some of its strength and provides a tentacle of tone that prehends the unison and octave notes with which it is combined. This makes for cohesion. But many examples of the quintaton are a failure because the twelfth is too pronounced, while the fundamental is so attenuated that it is not obvious that any double has been added. I recommend a fourth mouth cut up a fourth of the width and rollered, a good scale being CCC, 5 in., CC, 3⅜ in., tenor C, 2¼ in., middle C, 1½ in., treble C, 1 in. The quintaton is also employed in 8 ft. and 4 ft. pitches, the latter being called a **quintadena** by Hope-Jones.

CHAPTER V

The Reeds

THE mechanism of the organ reed pipe has been described in Chapter I, and the characteristic quality also defined. We saw that the first seven or eight harmonics are more or less of equal amplitude when compared with those which are higher in the series. This characteristic is due to the tongue vibrations and their effect on the air flowing into the shallot cavity. The tube or resonator reinforces certain harmonics, in particular the lower ones, according to its shape and length. Reed stops are divided into chorus and imitative (or orchestral) types, and in this chapter we shall consider the chorus reed only. It is called by this name because it forms part of the basic tonal structure of the modern organ; for although an organ can consist of diapasons only or of flue-work only, there is no point in omitting the reeds unless circumstances render their inclusion impossible. In the modern organ the great manual has come to be regarded as the "diapason organ," while the swell manual is the "reed organ." Since reeds present a definite tonal contrast to diapasons, this is a sound arrangement. If diapasons are included in the specification of the swell organ, they are not essential to the fundamental character of this department; and the same may be said of the reeds if introduced into the great organ. The reeds of the swell organ, however, are not so powerful as to dominate the diapason chorus of the great. The more powerful reeds are relegated to another department such as the "solo organ" or the "bombarde division." The whole subject of tonal planning is discussed in Chapter IX, and the disposition of the various reed stops is a subject that properly belongs to this later chapter. It is necessary, however, to know that there are various types of chorus reed which within limits can be assigned to any of the main divisions of the organ according to the design of the builder. Thus, it is easily possible to encounter a **trumpet** or a **tromba** which in one organ forms part of the reed chorus of the great manual while in another organ the same type of reed will be found—rightly or wrongly—in the swell or in the choir. Furthermore, a trumpet or tromba enclosed in a swell box sounds different in certain respects from a trumpet or tromba on an open chest, as may be proved by transferring the pipes from one position to the other and noting the change of effect.

The **trumpet** is the normal chorus reed; its harmonic content is developed substantially up to the sixteenth partial: above that the harmonics are much weaker up to the twenty-eighth, and some are missing. The fundamental is only half the strength of the third harmonic, while the fourth, fifth, sixth and seventh harmonics are also stronger than the first, the eighth being about the same as the first; the most prominent harmonic is the second. Broadly speaking we may say that the harmonic curve exhibits a fairly rapid drop in strength after the seventh or eighth partial, whereas the string-toned flue-pipe maintains in comparison a more sustained harmonic emphasis up to the twenty-eighth partial. The **tromba**, on the other hand, is distinguished from the trumpet by possessing a harmonic content characterised by a gradual decrement from the first to the sixteenth partial, the fundamental being the strongest and the octave almost as strong;

but the curve shows the same typical reed characteristic at its commencement. At the other extreme of harmonic development we have the French **trompette** which owes its fiery quality to the presence of the higher overtones with a weaker fundamental in proportion.

We must now see how these three types of chorus reed differ in construction, design and voicing.

1. The **trumpet** has "closed shallots," that is, the opening in the shallot-face is triangular and occupies about half the length of the shallot as shown at E in Plate IV. The relative length of the resonator to that of the vibrating portion of the tongue is of supreme importance for the production of normal trumpet quality. The tube should be tuned "at resonance," which means that the note of the tube should approximate to that of the tongue, though it is not necessarily identical in pitch. The exact relationship depends on the pitch of the note the pipe is expected to give: if a low note in the CC (8 ft.) octave, the pitch of the tongue during vibration should be a whole note higher than when the tube is added—the tube being fitted separately to the socket of the pipe in the case of the larger pipes. The smaller pipes—usually from 4 ft. up—are made in one piece and the adjustment of tube-length and tongue length can only be determined by the voicer's ear. The tube-length is adjusted by the slot at the top of the pipe, while the tongue-length is adjusted by the tuning spring which is made to slide up or down the surface of the tongue to the required point. To quote an example by way of illustration, a middle C (2 ft.) trumpet pipe having a tube (inverted conical in shape) whose diameter is 2⅜ in. at the top would be 1 ft. 8½ in. long to speak middle C 261 cycles, with a slot for regulation of tube-length almost closed up, and the tongue would be tuned to vibrate at a length of 1⅛ in., **assuming the correct thickness of brass for the tongue in relation to the wind pressure employed.** The pipe would speak "at resonance point," if so treated, with a pronounced second harmonic. If it did not, a slight adjustment of the slot would ensure that it did so. The tone would be "true trumpet tone" in accordance with the Willis standard. Of course, the tongue must be correctly curved, and the pipe properly made. One little fault in any of the details of design, construction and treatment spells failure—and a sorry failure. Reed voicing is a fine art and few there are who can be numbered among the adepts. The only way to learn the meaning of real trumpet tone is by hearing an example by a past master such as Willis.

The choice of wind pressure is very important when dealing with chorus reeds of the normal trumpet class. Father Willis could produce beautiful examples on 3½ in. wind, as is evidenced by many of his swell reeds. It was only at the latter period of his career that he increased the pressure to double (7 in.) for his swell reeds. Arguments can be adduced in favour of both the low and the high pressure treatment, but if it is desired to combine the chorus reed with the diapason chorus the low pressure reed is to be preferred because high pressure increases the amplitude of the fundamental harmonic. Since the diapason possesses a strong fundamental, it is contrary to the laws of tonal blend to superimpose other tones possessing a strong fundamental on the diapason chorus. Therefore low pressure reeds are more likely to harmonise with the flue chorus without swamping the latter or clashing with it (as the case may be). It is not easy to obtain good results from a low pressure trumpet unless one has the technique at one's fingers' ends. I have found myself—and I believe there are many others who are prepared to endorse my opinion—that **soft** brass is preferable to hard brass for the tongues of low pressure chorus reeds. It is not possible to convey in words the actual curvature that ought to be given to the tongues of low pressure trumpet pipes. The curve must make a very definite start at the tuning point (where the tuning spring is set) and be gradually increased right up to the wide end: yet to say this is not to disclose the true curve, since there are minute deviations from the parabola in this "sweep" that make all the difference to the result. Too much or too little "end curve" will ruin the tone; but one thing is certain—the "shadow" that creeps along the space separating tongue and shallot when the tongue is deflected by the finger should be on the slow side as it passes along the final portion. In no case should it dart across this short strip of line, represented by **f . . . g** at H in Plate IV. (Further reference to this figure will be made in the chapter on voicing.)

The **weighting** (or **loading**) of reed tongues is entirely a matter for the individual voicer to decide. There are those who condemn the practice altogether for chorus reeds. The device is applied to the lower portion of the stop and not carried up any further than is necessary. Since a loaded tongue tunes at a shorter vibrating length it is obvious that it cannot so readily produce the higher overtones: it is felt by some, therefore, that the tongues should be left free to generate their natural harmonics throughout the compass of the stop as is the practice in France. Here again, arguments can be adduced for both types of treatment: it just depends on what the designer wants. The unweighted tongue of an 8 ft. reed pipe for instance is rich in overtones but weak in fundamental. For a manual reed this may be an advantage, but a pedal reed would presumably require more fundamental. In a non-resonant building which does not favour the fundamental tone, I consider weighting essential. The early Victorian reed had no weights in the lowest octave and the result was a powerful bass out of all proportion to the middle and upper registers. If an attempt is made to modify the power of these bass notes by tuning the pipes on the sharp side and lengthening the tubes, they will develop a "choking sound" which cannot be tolerated. The weighting of the long tongues of such pipes solves the problem of regulation, if it does nothing else. It is possible, in designing a new reed, to reduce the scale of the lowest octave of pipes and also the diameter of the tips so as to enable the voicer to obtain a reasonably moderate strength from each pipe in this octave without having to resort to weighting. The quality is then thin and fiery, if this is what is wanted. The weights, if employed, are fitted to the lowest octave and a half for pressures below 3½ in. and carried up higher as required, if the pressure used is increased. Willis brass weights give a distinctive quality producible by no other kind of weight, but they introduce certain difficulties in the voicing and treatment of the tongues which only a skilled technician can master. I remember, many years ago, receiving a letter from a highly skilled reed voicer—a man of at least thirty years' experience—whom I had asked to voice a trumpet for me with brass weights. He wrote: "Sorry, but I prefer to use the usual felt and lead weights, if you have no objection: brass weights buzz so." And so they do, if one has not acquired the knack of adjusting the curvature of the tongue to suit them.

The question of scaling is a moot one. The modern tendency is in the direction of small-scaled pipes which have been shown to possess better blending qualities than large-scaled pipes. Large scales produce more power and more fundamental tone, but not better quality. The limit fixed by Willis for all normal purposes is 4½ in. at the 8 ft. pipe. Generally speaking, the smaller the scale the lower may be the pressure; but the reverse does not hold good that higher pressures require larger scaling. The best pressure for a given scale is entirely determined by the voicer's personal conception of what constitutes the ideal trumpet for a particular tonal scheme. No rules can possibly be laid down, but it may be suggested that the limits lie between 2⅜ in. and 7 in. wind for normal cases.

A list of trumpet scales is appended, based on the Willis standard:

CCC	7 in.	6 in.	5½ in.	5 in.
CC	4½ in.	4 in.	3¾ in.	3½ in.
Ten. C	3⅜ in.	3 in.	2⅞ in.	2¾ in.
Mid. C	2¾ in.	2½ in.	2⅜ in.	2-5/16 in.
Treb. C	2¼ in.	2 in.	1-15/16 in.	1⅞ in.

The half measure falls on the 32nd note in the 8 ft. octave, and is increased to half on the 37th or 38th from 4 ft. up.

It is customary to-day to give the upper octaves of chorus reed pipes a double-length tube, the object being to secure greater purity of tone combined with adequate power. These double-length pipes are called "harmonic," since they speak the octave above normal pitch. It is not necessary to pierce a hole in the tube for this purpose, in fact such a proceeding would not be advisable: the tongue is tuned to vibrate at the octave above and the tube exercises complete control. The scale of the harmonic tube is the same as that of the octave below. Thus, if the scale at middle C (2 ft.) is 2½ in., that of the treble C tube is also 2½ in. (instead of 2 in.): the treble C pipe could be made to speak middle C quite satisfactorily, the shallot being also the same **length** though not the same in cross-section (which is that of the treble C shallot). To make this perfectly clear I will give the particulars of the middle C pipe of normal length and those of the treble C pipe speaking its harmonic (an octave above middle C).

MIDDLE C: Length of tube, 1 ft. 9 in.; diameter at top, 2½ in.; length of shallot, 2½ in.; length of opening, 1¼ in.; diameter of head of shallot, ⅜ in.; of tip, 7/32 in. (inside); tuning length of tongue, 1⅛ in. (unweighted).

TREBLE C (harmonic): Length of tube, 1 ft. 9½ in.; diameter at top, 2½ in.; length of shallot, 2½ in.; length of opening, 1 in.; diameter of head of shallot, 5/16 in.; of tip, 3/16 in.; tuning length of tongue, ¾ in. (unweighted).

Pressure, 4½ in.; pitch, 258.5 cycles at middle C at 50° F.

The precise point at which the harmonic pipe should be employed depends on the (1) pressure, (2) type of tone and quality aimed at, and (3) the scaling of the stop. A small scale usually requires a harmonic treble to maintain the balance of power and preserve purity of tone. Pressures below 3 in. are inadequate for obtaining the requisite strength and harmonic development from the upper octaves. On a pressure of 4 to 5 in. the first harmonic pipe may be G above middle C: below this point harmonic pipes on medium pressures are apt to give a nasal tone out of keeping with the character of the stop, while attempts to eliminate this nasality result in reducing the harmonic content of the note so that it merges into "**tromba tone.**"

The actual weight of the load (be it brass, lead and felt, or any other material) can only be assessed in relation to the scale and pressure employed in combination; and the same applies to the thickness of the tongue (gauge of brass). The gauge should never be thicker than is required for the purpose—a rule sadly ignored by some voicers, but most carefully observed by Willis. Aluminium (ninety per cent. hard-rolled), initiated by Mr. C. H. Clarke, as a material for reed tongues, has its primary use for the top octave of the trumpet where reed pipes are often replaced by flue pipes, and also for the top octaves of the 4 ft. trumpet or **clarion,** which are almost invariably made of flue pipes unless the higher pressures are resorted to. It is possible by employing tongues of this material to maintain the desired brilliance of tone right up to the top note, and I may add that the pipes keep in tune for much longer periods than those fitted with brass tongues. In my organ at Stagsden I have a trumpet fitted with aluminium tongues from middle C to top note and voiced on 4⅞ in. pressure. The scale follows the third on the list above given and the first harmonic pipe is middle G♯. The pipes from B below middle C to B below treble C are fitted with cowls, and the tongues are brass-weighted up to tenor G. The four top pipes were kindly made and supplied by Mr. C. H. Clarke of Snaresbrook, replacing original flue pipes. There is also a CCC (16 ft.) pipe standing on a one-note chest and playable from the pedal key (when required !). This and all the other pipes were made and supplied by Messrs. F. J. Rogers, of Bramley (Leeds). The 16 ft. pipe is 7 in. diameter at the top, has a brass-weighted tongue, and is mitred as shown in Plate III to an overall height of 12 ft. 6 in. The actual length of the tube from tip to top is 16 ft. 2 in.

If a trumpet pipe is tuned on the sharp side, that is, if the tube is allowed to be longer in respect to the vibrating length of the tongue, the pipe loses its character of trumpet tone and becomes what voicers call "close-toned." If the tongue is made too short as a vibrator the tube will take control and the note will fly up to a harmonic: it is therefore necessary to provide against this contingency in the design and treatment of close-toned chorus reeds. Thus the **tromba** was evolved. Hope-Jones, assisted by Franklin Lloyd, developed this smooth tone from reed pipes, and other builders have followed in his wake producing very refined chorus reeds from much smaller scales than Hope-Jones used. Vincent Willis introduced the "filled-in" shallot shown at B in Plate IV, and this shallot is almost invariably used for the tromba and horn type of reed. Heavy pressure, thick, hard brass tongues, weighted right up to treble C, filled-in shallots, narrow tips for the tubes, and harmonic length tubes commencing as low as possible, with the tongues tuned on the short (sharp) side—all these factors combine to produce smooth tromba tone. The higher the pressure, the bigger the tone; for increased pressure is essential to power combined with smoothness. The fundamental is no longer subordinated to the harmonics above it, as in the case of the trumpet, but is the predominant harmonic. At one time this type of chorus reed found great favour with the generality of organists, and especially with cathedral organists; but the pendulum of opinion has begun to swing back to an appreciation of the more normal type, though there is still considerable divergence of opinion as to the comparative merits of low and high pressure chorus reeds of the normal trumpet class.

The swell trumpet in Victorian organs was usually labelled **cornopean,** a misnomer if the type of tone aimed at was the trumpet. The explanation lies in the fact that the cornopean was given a large scale, often as much as 5½ in. or 6 in. at CC (8 ft.), in order to increase the power and breadth of the tone on the low pressures then in vogue. But the cornopean is properly a **horn,** and the horn belongs to the category of smooth reed tone. The **French horn,** which represents the acme of smoothness in the realm of reed voicing, is described in Chapter VIII.

The **trompette** is a trumpet fitted with open shallots as shown at C in Plate IV. As mentioned above, the French builders have always favoured this type of shallot which encourages the higher harmonics and also certain inharmonic overtones (not exact multiples of the first harmonic). The shallot shown at G is a compromise between E and C, and is to be preferred to C for the production of fiery trumpet tone. Nevertheless, I have succeeded in obtaining a satisfactory trumpet quality from the parallel opening (as at C) on as low a pressure as 2⅜ in. by giving the tongues a "minimum curve" and weighting them (with felt) as far up as G above middle C. The weights, needless to add, are very minute in size, just enough to lend the necessary refinement to the tone and counteract the inharmonic component of the aerial system in the shallot. The actual power of such a reed would be quite small, but there can be no doubt as to its fine blending quality. It is capable of adding lustre to the diapason chorus on an open soundboard without the least suspicion of aggressiveness. Many connoisseurs of tone regard the trompette as the ideal type of reed for the swell organ, and I am inclined to agree. Harmonic trebles are desirable if the pressure is higher than 4 in., as the open shallot needs this kind of control in the upper octaves. One disadvantage of the high pressure trompette is its tendency to "cluck" on release of the note (due to the tongue closing and opening the shallot suddenly on the cessation of wind supply and producing the shallot note only). The triangular opening of the "closed" shallot considerably mitigates this disagreeable sound, though it does not completely eliminate it. However, when reeds are played in chords, and more especially when they are combined in chords with other stops, this unfortunate feature is not noticeable. It is very important to see that the tongue is not given the same end curve as for the closed shallot: in fact, the curve should be more evenly distributed in view of the extended opening.

Opinion is divided as to what category the **oboe** should be placed in. The shape of pipe is shown in Plate III. Its tube is of narrow scale, surmounted by a bell. The top of the bell is either fully capped with a slot cut out below or else half-capped as shown in the drawing. In tone the oboe is not imitative of its orchestral prototype—a pipe called "orchestral oboe" claims to be an imitation—but is a miniature version of the chorus reed. It may be voiced as an echo trumpet or as an echo horn, and the **contra oboe,** 16 ft. is definitely a double echo horn. I therefore class the oboe with the chorus reed, although it is much used as a solo stop. "Full to oboe" is often considered as a miniature "full swell effect," and this it can be if the oboe is voiced as an echo trumpet, with not too much tube control. The shallot is similar to that of the trumpet, but has less taper and a slightly shorter opening. The tongues are given a flatter curve than for the trumpet, and the sweep is not so pronounced at the initial portion (i.e. from the tuning spring). In other words, the distribution of the curve is more evenly maintained than for the trumpet.

The length of the tube at tenor C is approximately 2 ft. 6 in. plus the length of the bell which is 9 in. The length of the trumpet tube speaking the same note would be 3 ft. 9½ in., so that the oboe, with its bell included, is 6½ in. shorter. The diameter of the top of the bell at tenor C is approximately 2⅝ in., while that of the tube at the point where it meets the narrow portion of the bell is 1¼ in. only. When the top octave of pipes is reached the bells become longer than the tubes: for instance the 6 in. C pipe consists of a tube 1½ in. long and a bell 2¼ in. long, the diameter of the bell being 1-3/16 in. at its wide end and 9/16 in. at its narrow end. It should be noted that these are the dimensions of the "trumpet oboe" and not of the "horn oboe." The latter type would have a narrower tube-head, thus making the bell wider in proportion so as to reduce the harmonic content of the note. It is usual to discontinue the bells below the 4 ft. pipe (tenor C) and employ bassoon pipes for the lowest octave. These are merely small-scaled trumpet pipes, of the order of 2½ in. diameter at the 8 ft. pipe, the length being in proportion to the scale. (Since the conical reed tube length is shorter in proportion as the diameter at the wide end is smaller, and vice versa, the bassoon would have a much shorter tube than the normal trumpet). The top of the tube is commonly covered with a complete cap, a slot being cut out of the tube just below the cap. The true oboe quality cannot be maintained in the bass by bassoon pipes, and the bells should if possible be continued down to the bottom note. Father Willis introduced a number of really beautiful examples of the contra oboe (labelled "contra hautboy, 16 ft.") in his swell organs on low pressure with bells down to the bottom note. The scale at CCC was 6 in. and the lowest octave, loaded with brass weights, was indescribably mellow, every note being a pearl of beauty.

All the types of chorus reed above described can be made in 16 ft. and 4 ft. pitch as well as 8 ft. The **double trumpet** is the 8 ft. trumpet with an added 16 ft. octave, the scales at CCC being already given in the list on page 72. Even in the 16 ft. octave there are those who would omit the weighting of the tongues. I have heard several examples of unweighted double reed basses, but have invariably found that the pipes are unable to attack their notes or release them properly. The weight seems necessary to control the initial movement of the extra long vibrator, and Mr. H. W. Homer's experiments with the stroboscope and oscilloscope have proved beyond question that a long tongue produces a cluster of inharmonic overtones. This is not to say that such a cluster of inharmonic overtones is necessarily detrimental to quality: I would be far from admitting any such thing; but if the pipe is unable to speak properly and firmly, there must be something wrong with its mechanism, and what is wrong seems to be the undue vibrating length of tongue. The **contra tromba,** 16 ft. obviously carries down the tromba tone, while the **bassoon** and the **contra fagotto** are small scaled trumpets, capped or uncapped as the voicer prefers, with a scale at CCC varying between 3⅞ in. to 5 in. The octave chorus reed or **clarion** has already been mentioned.

We come now to the most powerful of all organ stops, the **tuba.** This, too, may be a magnified edition of the trumpet or the tromba or the trompette according to its treatment. It is generally conceded that no pressure under 9 in. will produce the true tuba tone and power, but it would be extremely interesting to obtain the impartial opinion of a dozen organists and organ builders as to whether the stop labelled "tuba" in the organ at the Brompton Oratory is a real tuba or not. Speaking for myself I was completely deceived by the prodigious power and fullness of this stop at close quarters (namely in the organ loft) and was aghast at being informed by Mr. R. W. Davidson, its voicer, that it was on **five inch pressure only.** The extraordinary effect of this reed is apparently due to its acoustic environment, the tone being reflected (and considerably amplified) by the masonry behind and above the pipes. The quality is broad and mellow, yet by no means lacking in brilliance. An abnormal example, indeed. But in normal surroundings the tuba needs plenty of pressure. It should be harmonic from tenor F sharp to the top pipe on pressures exceeding 9 in., and the Willis tuba is usually on either 12 in., 15 in., 20 in., or 25 in. according to the power aimed at and the size of the building. For this standard type the maximum scale is 5 in. at CC, 3½ in. at tenor C. The tuba shallot is rather wider in scale than that of the trumpet, the middle C shallot measuring 2-9/16 in. long, with the length of opening 1 in., the outside diameter of head, ½ in., and the inside diameter of tip, ¼ in. The base of the triangular opening is also wider, almost the full width of the shallot-head. The top octave of pipes on the higher pressures are often given triple or even quadruple length tubes. The **tuba magna** in the organ at Liverpool Cathedral by Willis speaks on 50 in. wind and is harmonic from the lowest pipe. At the Atlantic City Auditorium (U.S.A.) there is a tuba on 100 in. with filled-in shallots.

The tuba, as already mentioned, may be a magnified tromba, and there are a number of examples by Harrison and Harrison and also by Compton. In order to obtain the requisite power for a large building with smoothness of tone it is necessary to employ pressures of the order of 20 in. There is a notable example by Harrison at York Minster on 25 in., and another at Wells Cathedral on 20 in.

The free-toned tuba or magnified trompette is not so common as the two preceding types. It has open shallots (with parallel openings) and small scaled tubes. In the swell division of the organ in Westminster Cathedral by Willis there is a trompette on 15 in. wind which in an ordinary church would produce a very powerful reed effect—unenclosed, it would certainly rank as a tuba of free tone. The limit of free tone, however, has so far been obtained by the Willis **trompette militaire,** of which there are two examples, one on 20 in. at Sheffield Town Hall, the other in St. Paul's Cathedral on 30½ in. The tubes are made of spun brass with flared tops in imitation of the orchestral instrument.

The tuba is often extended into the 16 ft. and 4 ft. pitches, and many solo divisions of large organs contain **contra tuba, tuba,** and **tuba clarion.**

Organ builders have from time to time exercised their ingenuity in devising various kinds of headgear for the tubes of reed pipes. These are illustrated in Fig. 6. The **compensator** (A) and the **cowl** (D) have already been mentioned in reference to the open flue pipe, but they can be applied to the reed in order to obtain special effects. The compensator makes the tone "horny" and reduces the harmonic content of a reed so treated; while the cowl increases the power of the pipe and also slightly reduces the harmonic content (though not to the same degree as the compensator). The addition of the cowl tends to convert a trumpet into a tromba, though not a tromba of the close-toned type: perhaps a "tuba minor" would be a more fitting description of the tone. The **umbrella** (C) was one of Vincent Willis's ideas, fitted to a few of his cornopeans, but not, to my knowledge, adopted by any builder. It is certainly an improvement on the capped reed. The **flare** (B) was introduced by Herbert Norman for the purpose of producing very big chorus reed tone in a large building, but unfortunately the long wide formation of this conical device encourages certain inharmonic overtones. At E is shown a device for shortening the long tubes of the 16 ft. and 8 ft. octaves of reeds, introduced by Haskell, though usually the tubes are mitred for this purpose, as shown in Plate III.

CHAPTER VI

The Pedal Organ

WHO invented the pedal clavier, enabling the organist to use his feet as well as his hands? Was it Albert Van Os (1120), Nicholas Faber (1360), Traxdorf (1468), or Gregorius Kleng (1494)? We shall probably never know. It is, I think, safe to say that the pedal was in use by the end of the fourteenth century. In this country the pedal organ was more often than not a meagre affair consisting of one to four stops till towards the latter part of the nineteenth century. Early Victorian instruments often possessed an octave and a half of "pedal pipes," which consisted of open wood pipes of 16 ft. pitch. Quite a large number of organs consisting of from twenty to thirty stops spread over three manuals had only two stops on the pedal, a 16 ft. open wood and a 16 ft. stopped wood (bourdon). Later it became the fashion to add an octave stop to the pedal organ in the shape of an open wood "violoncello, 8 ft.", which was as far from representing the orchestral instrument of that name as could be conceived. Even Hopkins and Rimbault in their monumental treatise on "The Organ" only specify four stops for the pedal of a two-manual organ containing twelve stops on the great manual and ten stops on the swell manual. For an organ of three manuals and fifty speaking stops, however, they specify a pedal of eleven stops.

Now the pedal does not merely provide the bass of the Organ: it is an independent clavier making it possible for the player to introduce a separate melodic part with his feet when desired. Pedal passages are constantly written in organ music which can only be brought into due prominence and made independent of the manual parts by the use of suitably designed and voiced pedal stops. The organs of Germany were provided with completely equipped pedal schemes enabling the pedal to play an important part in the rendering of polyphonic music, a part which was denied to English organists unless they were fortunate enough to preside at organs possessing fifty stops or more. The introduction of derivation and extension methods has revolutionised the English pedal organ and made it possible to provide the necessary complement of stops at a considerably reduced cost.

The standard or unison pitch of the pedal organ is an octave lower than that of the manuals, namely 16 ft. pitch. Thus, the manual open diapason is an 8 ft. stop while the pedal open diapason is a 16 ft. stop. As a rule only one note is played on the pedal at a time, but it is, of course, easily possible to play two notes at a time or even three. Since, however, only one note is usually played and the striking of chords is comparatively rare on the pedal, the main objections to borrowing and extension for providing the various stops fall to the ground, quite apart from the economic aspect which constitutes a powerful argument in its favour. A complete 16 ft. manual stop is a costly affair, and if it can be made use of as a pedal stop, why not? It is too often assumed by the objector that the manual double so duplexed must be used on both manual and pedal simultaneously, but again why? It does not follow in the least. **It is quite possible to use**

the borrowed and extended ranks independently as pedal stops as if they belonged to the pedal only and not to the manual. This is entirely a matter for the player: if he knows his job, he can so use his pedal stops that no one in the audience can possibly know that the stops are not independent as in the old German organs. They **happen** to be borrowed, that is all.

The modern practice of duplexing 16 ft. manual stops on the pedal and of adding the octaves by extension of the unison has had a further beneficial result not sufficiently realised. It has led to the provision of an increased number of manual doubles in the modern specification, it being felt that the opportunity of providing material for more pedal stops should not be missed. Thus, the great manual is given its double diapason and/or its bourdon: the swell manual is given its double trumpet or contra fagotto: the choir division its double dulciana or contra salicional: the solo division its contra viola: the echo division its lieblich bourdon; and so on. Since each one of these doubles is duplexed on the pedal, their cost is justified. Moreover, since many of these manual doubles are enclosed, they serve as expressive pedal tones, they and their octaves (by extension). All this is a great gain.

It must, however, be borne in mind that there are certain stops which are specially suited for use on the pedal only and are therefore designed for this purpose. It is only natural that organ buiders should from the earliest times have adopted large scales for the pedal department with a view to obtaining a more ponderous tone from the pipes than would be desirable on the manuals. This is not to say that all pedal stops have been or are designed to produce a dull, heavy tone—certainly not on the continent—it means that in comparison with the treatment given to manual stops that given to the pedal stops is bolder and on a grander scale. I refer to the independent ranks of the pedal such as the open wood, 16 ft., the open metal, 16 ft., the bourdon, the trombone. And in this connection I ought to say that although practically every manual double is duplexed on the pedal in the modern organ, a certain number of independent 16 ft. basses (from CCC to BBB) are usually provided on the pedal even if the upper portion of the stop (from CC up) is duplexed from a manual stop. It may be that the only independent rank is an open wood, 16 ft., and that all the rest of the pedal stops are borrowed from the manuals; or again, it may be that the pedal trombone, 16 ft. is independent from CCC to BBB, with the remainder from CC to top G duplexed from the manual tromba, 8 ft. Or again, there may be an independent wood violone, 16 ft. so designed and voiced that it would not be suitable as a manual double. The 32 ft. pedal stop, be it flue or reed or diaphone, is usually an independent rank at least in the lowest octave. When the organ in the Royal Albert Hall (London) was rebuilt, the 32 ft. metal open diapason on the pedal was duplexed on the great, thus providing the rare example of a complete manual open 32 ft. stop. Here we have an instance of duplexing a pedal stop on the manual, but it amounts to the same thing if the pipes are borrowed from the manual in order that they may be available on the pedal also.

Let us turn our attention to the various pedal stops.

I. **FLUE WORK.** First and foremost comes the open diapason, 16 ft. of wood or metal. If the pedal organ were merely the bass extension of the manuals the pedal open diapason would be the bass extension of the great manual diapason, 8 ft., but this is not so. It provides the diapason bass for the manual diapason **chorus**—a very different thing. Therefore, if the pedal diapason is duplexed from the great manual double diapason it is not suitable as a bass to the diapason chorus but only to the unison diapason with or without the principal.

This is an important point. The "open, 16 ft." on the pedal should have at least an independent lowest octave to justify its existence: with this proviso the remainder of the stop may in certain circumstances be derived from the No. 1 open diapason of the great. But as a rule the pedal open, 16 ft. is wholly independent from CCC to G (32 notes), and often to the G above so that an "octave, 8 ft." may be derived from it by extension. It has been the custom in English organs to make this stop a big pedal wood flute or tibia of large scale with no trace of diapason tone. A very common scale was 16 in. by 14 in. at CCC (16 ft.), the cap and block being formed as shown at C in Plate II. A smaller scale with the block and cap as at A would give a tone more in keeping with the name of "open diapason, 16 ft." so often found on the stop-knob: 12 in. by 10 in. at CCC, as recommended by W. T. Best, is a good scale. A smaller scale still, such as 10 in. by 8 in., or 9 in. by 7 in., would produce a geigen bass, 16 ft. Roller-bridges would in the latter case be necessary. The above stops are assumed to be voiced on a pressure not exceeding 5 in. On a pressure of, say, 8 in., and with a mouth cut up two-fifths of its width and rollered, a powerful string tone could be generated: such a stop would be labelled "contra bass, 16 ft." (or "contra basso").

The metal open, 16 ft. is usually made of zinc, though there are many examples made of spotted metal (notably by the late T. C. Lewis), and even of tin. The scale varies between 9 in. and 12 in. at CCC, with a two-ninths mouth (as a rule, though not invariably), cut up a third to four-elevenths of its width. The upper lip and leaf are made of plain metal in the case of a zinc pipe and soldered in. The scaling may be reduced to 8 in. at CCC for the purpose of developing the harmonic content (as we saw in the wood pipe treatment), with roller-bridges. Thus a metal geigen bass is produced.

The dulciana, 16 ft. is a beautiful pedal stop for soft manual combinations. If it is not borrowed from the manual, it may be given a somewhat larger scale in the lowest octave, such as 6½ in. (instead of 6 in.) at CCC, or if of wood, 7 in. by 6 in. (instead of 6 in. by 4¾ in.) There is a singularly beautiful specimen at the church of the Cowley Fathers, Oxford, by Thynne, made of wood and labelled "contra basso."

The violone, 16 ft. gives the maximum of string tone and is accordingly scaled with this object in view. The metal violone is not a conspicuous success unless it is treated as a "contra bass" on heavy pressure as above indicated. Low pressure examples do not give the blaze of harmonics that issue from a well-voiced wood pipe. If metal is employed it is advisable to avoid nicking the languid or lower lip, since nicking damps the harmonics. If the pipes are made of zinc they should have spotted metal lips. A good scale would be 7 in. at CCC with a fourth mouth cut up a third with bevelled upper lip, a roller-bridge being, of course, essential. A wind pressure of 5 in. is recommended. A smaller scale, such as 6 in., is often used, but this is more suitable for a manual contra viola.

The wood violone, as introduced by Schulze and exhibited at its best in the pedal organ at Hindley, is a magnificent stop, producing a richness of tone which compares very favourably with its orchestral namesake. The Hindley stop measures 5½ in. square at CCC, the height of the mouth being a full third of its width. A sketch of this pipe with the unusual type of roller-bridge employed is given at G in Plate II. The pressure is 3¾ in. Whiteley made a "contra basso" of wood for the organ at the Battersea Polytechnic Institute, with a scale of 6⅝ in. by 4¼ in. on a pressure of 10 in. Schulze's pipe is un-nicked, while Whiteley's was nicked on the cap only.

The bourdon, 16 ft., often labelled "sub bass," is the most economical of pedal stops owing to its half length pipes. In order to get sufficient weight of tone it is usually made of wood, the scale varying from 6 in. by 5 in. to 13 in. by 11½ in. The former scale is too small except for a lieblich bourdon, in which case the pipes are given the German type of cap and block as shown at A in Plate II. The latter scale is that which the celebrated Dr. L. G. Hayne used to advocate and is really too large. The reason why such a large scale was thought necessary was because of the English type of cap and block which necessitates a comparatively low mouth for good speech: a low mouth unfortunately promotes an anticipatory twelfth familiarly known as the "cough"; and in order to avoid this distressing feature a large scale was adopted. But the German cap and block provides a far better remedy: it enables the mouth to be cut up much higher and renders large scaling quite unnecessary, nothing more than 9 in. by 7 in. or 8 in. square ever being required. Some builders have introduced a larger scale with this type of pipe of the order of 10 in. by 9 in., "clothing" the flue and upper lip with splitskin with the object of producing a ponderous tone approaching that of the open wood, 16 ft. of the early Victorian builder. The effect of one example which I heard was certainly that of a tibia bass and was quite adequate as a pedal bass for a full great to mixture combination as far as weight of tone was concerned: in other respects it was not adequate, of course, since it failed to provide the necessary harmonic development which a diapason chorus demands from a pedal bass. The mouth of a bourdon pipe fitted with German cap and block is usually cut up four-fifths of the width for the smaller scales, five-eighths for the moderate, and half for the larger scales. The upper lip is frequently arched, but Schulze preferred the straight-lined lip.

Mr. Ernest M. Skinner (U.S.A.) has devised a special type of wood block which he claims to produce an "unbelievably improved" result from a stopped wood pedal pipe. The front edge of the cap is bevelled instead of being flat, while the top surface of the block inside the pipe has a horizontal semi-circular trench-groove cut out of it just beyond the flue-edge. The front edge of the block is bevelled as in the German model. The object of the cut away parts is to remove all deadening influences affecting the windsheet at the mouth so that it may be the more completely controlled by the vibrating air column in the pipe itself. The formation of the cap and block is illustrated in Plate II, N.

Yet another device of Mr. Skinner's is to place a sheet of zinc on each side of the flue so that each upper edge projects about a quarter of an inch above the flue level. Large wood pipes, open or stopped, already in place in an organ can be so treated without removal.

At J in Plate II is shown an ingenious attempt to produce the effect of an open pipe from one of half length as devised by William Haskell, a famous American voicer who has many novelties in the way of organ pipe construction to his credit. This pipe is tuned by means of a sliding rod which adjusts the space intervening between the two portions of the pipe at the mouth end. The roller-bridge ensures prompt speech with a complete absence of overblowing.

It is possible to obtain two notes from one bourdon pipe (and, if desired, from one open wood pipe) by arranging for the lower pedal key to admit wind to the pipe in the usual manner, and the next key above to open a disc-valve which normally covers a hole bored in the back plank of the pipe immediately opposite the mouth. If the diameter of this hole is equal to the height of the mouth the pipe will speak a semitone higher. So far as I am aware, this ingenious device is due to John W. Whiteley.

In a small organ, or where space is strictly limited, it is permissible to obtain two distinct powers from a single set of bourdon pipes, provided that only the lowest thirteen (or at most eighteen) pipes are so treated. Two ventils are attached to the bourdon chest, the one trunked to the low pressure on which the stop is voiced, the other to a higher pressure. Two drawstops are provided, operating each ventil, one labelled "bourdon" (on the higher pressure), the other "echo bourdon" (on the lower pressure). The upper portion of the stop not so treated must, of course, be planted on a separate chest. At Stagsden Church, I have been compelled to adopt a similar device, much against my will; but the necessity of two powers was paramount, and the effect in the building has justified the arrangement. In this case, only one pressure is used, the second ventil supplying a reduced head of wind at the same pressure of 2½ in. to the chest through a smaller hole (which can be adjusted to any size within limits). An "echo bourdon" of limited compass has thus been obtained at a cost of a few shillings. The echo version is, of course, not exactly in tune owing to the difference in the pressure applied, but in the lower notes the slight out-of-tuneness is not sufficiently marked to be noticed.

The 32 ft. open wood pipe produces an effect of which the King of Instruments alone may boast. It cannot be reproduced by any other means, as far as I am aware, save that of a wood or metal pipe thirty-two feet long and of adequate scale. Not even the diaphone can produce the characteristic "seething, bubbling" effect of the traditional pedal pipe. Any attempt at imitation by means of an oscillating valve or any other electronic system must inevitably fail owing to the sheer incapability of a loudspeaker diaphragm to handle such a sound wave without "frequency doubling." There is no acoustic system of tone-production that can vie with the aerial mechanism of a 32 ft. pipe of wood measuring, say, 29 in. by 25 in. at CCCC (the scale adopted by Mr. Willis at Liverpool Cathedral). True, the actual fundamental frequency of sixteen vibrations per second cannot be distinguished by human ears: the lowest frequency in the audible range is twenty vibrations per second. But it does not follow that the **sound** emitted by the CCCC pipe is lost on the listener: far from it! It has a psychological effect on the listener that no other sound is able to produce, and only a 32 ft. flue pipe can do it. The smallest scale worth considering would be 18¼ in. by 14¼ in., which is that of Schulze's at Armley, and 25 in. by 20 in. is much nearer the mark if any real grandeur of effect is to be secured. The 32 ft. metal pipe (of zinc or plain metal or tin) may measure anything between 15 in. for a contra violone to 24 in. for the real diapason effect. The fine 32 ft. open diapason of tin at the Royal Albert Hall has already been mentioned: there are many examples of both wood and metal 32 ft. stops in our cathedrals.

The tremendous cost of these huge pipes, to say nothing of the height they take, has impelled organ builders to devise cheaper substitutes purporting to give a similar effect. The sub-bourdon, if given a sufficiently large scale, such as 15 in. by 13 in., is capable of producing a moderately tolerable result **in favourable acoustical conditions.** One organ builder, gifted with a sense of humour, has called it "an expensive draught," and Schulze volunteered the opinion that it was not worth the material of which it is made. That great church musician, the late Rev. Sir Frederick Gore Ouseley, experimented with pyramidal-shaped pipes in an attempt to produce 16 ft. tone from a stopped pipe only 2 ft. 9 in. long (the "Pyramidon"). The CC pipe measured 8 in. square at the mouth and 27 in. square at the top (a ratio of 1 : 3.4 approx.). The idea of utilising the principle of box resonance, now so familiar to wireless enthusiasts, for the production of low frequencies must, therefore, be placed to Ouseley's credit; but the first practical demonstration of it in the production of 32 ft. tone was made by Mr. John H. Compton in the form of "cubes." These cubes are totally enclosed boxes, the only opening being the mouth which is situated in the middle of the front plank and about a quarter way up from the bottom of the box. A series of holes is arranged in a line above the mouth (or at any part of the plank where convenient for access) which can be covered or uncovered by means of disc-valves operated by the pedal keys. The size of each hole can be accurately adjusted by means of slotted wooden plates. Only two cubes are required to produce the twelve lowest notes of the 32 ft. pedal stop. With two more cubes a further octave can be added to the compass. These cubes are very effective in certain buildings, but not in others: all depends on the acoustical environment.

The reputed discovery, two centuries ago, by Tartini of the differential principle led to the introduction of a "resultant bass" tone by Abbot Vogler (1749-1814). If two notes are made to sound simultaneously, the difference of the two respective frequencies is said to generate a third frequency: thus, if we sound a note giving the pitch of CC (64 frequencies) and at the same time a second note sounding G above (96 frequencies), we get a differential frequency of $96-64=32$. A note of 32 frequencies sounds CCC, 16 ft. If, therefore, we (a) sound together CCC and GGG, or (b) GGG and CC, we get a differential frequency of 16 cycles, that is CCCC, 32 ft. CCC$=32$, and GGG$=48$: therefore $48-32=16$. Or, alternatively, GGG$=48$, and CC$=64$; therefore $64-48=16$. Thus, we may couple two notes of a bourdon or an open, 16 ft. stop, either in fifths or in fourths, and produce a resultant or acoustic 32 ft. tone. Mr. J. J. Binns much preferred to couple the fourth **below** to the unison instead of the fifth above in order to produce the effect of a 32 ft., but mathematically he was producing frequencies in the 64 ft. octave, since 16 ft. CCC giving 32 vibrations and the fourth below giving 24 vibrations produce in combination a differential of 8 vibrations. No doubt the "effect" would be more thunderous and perhaps more impressive than that produced by a quint, 10⅔ ft., but it only goes to show that resultant tones are nine-tenths illusory and one-tenth actual. The pedal quint as a separate and complete rank is none the less a very useful stop, quite apart from any resultant tones it may appear to introduce: it has the effect of **consolidating** the pedal tones into a firm and closely-knitted texture, though in order to secure this result the right kind of pipe must be selected for the rank and very careful and discriminative treatment given throughout the compass. **It is essential to experiment with a selection of C pipes in the actual building before arriving at a decision.** Such a stop cannot be designed in the factory. It is never necessary to introduce the differential effect in any but the lowest twelve notes of the pedalboard, since the actual 32 ft. tone can be duplexed from the open, 16 ft. or the bourdon. Some builders prefer to borrow the quint from the bourdon, others from the open, 16 ft. A separate quint is always best.

II. **REEDWORK.** We now come to the pedal reeds, which are invariably effective adjuncts to a pedal organ scheme. Continental builders have always favoured the pedal reed and introduced it much earlier in the order of priority than we have done in this country. True, half-length tubes—conical or cylindrical—have been much in evidence in continental examples, and they are better than no reed at all; but the full length reed is always preferable because it gives a more pronounced fundamental harmonic, which is what is wanted on the pedal.

It is generally conceded that an 8 ft. manual chorus reed requires, at least in theory, its 16 ft. complement on the pedal, but how often is this excellent principle carried out in practice in English organs? Some designers would introduce the 16 ft. pedal reed (trombone, for preference) as early as possible even in a small two-manual scheme: thus, for example, a pedal of four stops might in their view consist of bourdon in two powers, flute (8 ft.), flute (4 ft.) and trombone—a very excellent little pedal scheme of its type.

The 16 ft. pedal chorus reed was labelled "ophicleide" by Father Willis, and a truly magnificent reed it was (and is). The scale at CCC is 7 in. to 8 in., and the tongues are loaded with brass weights. A brass weight of three-eighths of an ounce would be appropriate for the CCC tongue vibrating over a wind pressure of 8 in., assuming the correct thickness for the tongue in question (say, 0.028 in.). For pressures up to 6 in. a tongue of .022 to .026 in. in thickness is indicated, with a load weighing 5/16 oz. The lowest octave is usually mitred as shown in Plate III, not only to reduce the height of the pipes but to prevent dust and dirt falling down the tubes. The Haskell re-entrant tube is shown at E in Fig. 6. Zinc may be used for the tubes as far as the top of the mitred portion: this latter should be of stout plain metal. It is permissible, however, to use an all-zinc tube with a wooden block. Smaller scaling can be used for this type of pedal reed, though, of course, one cannot expect to get the same weight and fullness of tone. The shallots used by Willis for the ophicleide are made to a special size and scale: the dimensions of the CCC shallot, for instance, are as follows:—

Diameter of head, 1-1/16 in.; length, 6 in.; diameter of tip, ½ in.; length of opening, 2⅝ in.; width of opening at base, 9/16 in.; thickness of brass, 3/32 in.

A smoother type of reed, which we may call the trombone, is producible by means of felt-and-lead weighting and a longer tube in relation to the vibrating length of the tongue. By "smoother" I do not mean to suggest that the brass-weighted reed with its tube tuned to resonance point is not smooth in quality: it is. I mean that the harmonic content of the trombone is definitely reduced and that in consequence the note does not give the characteristic "blaze" of harmonics that one associates with the Willis ophicleide. A close-toned pedal reed is not without its value in the pedal scheme: it introduces a contrasted effect which off-sets the richer quality of its free-toned brother. If power and weight are required, high pressure is essential. Messrs. Harrison and Harrison have produced many examples on 12 in. or more.

Wooden tubes are sometimes substituted for metal, and there are fine examples to be found in this country. The shallots may also be of wood and "filled-in." With a low pressure of wind it is probable that wooden shallots and tubes produce a more satisfactory result. The tubes are, of course, not round but pyramidal in shape, the scale of the 16 ft. pipe being 6 in. to 7 in.

32 ft. pedal reeds are made of metal or wood in the same way. The normal scale is of the order of 12 in. at CCCC. At Wesminster Cathedral Mr. Willis has a 32 ft. reed voiced on 30 in. pressure, the vibrating length of the CCCC tongue being about 3½ in. with a weight of 4 ounces. Another fine Willis example is at Huddersfield Town Hall on 12 in., and at Hereford Cathedral on 16½ in. At St. Mary Redcliffe, Bristol, there is an interesting example of an enclosed 32 ft. reed by Harrison. Another very interesting example by Walker occurs at York Minster: this has capped wooden tubes and was designed to give a soft 32 ft. reed effect of great usefulness. Father Willis produced a number of low pressure examples which have been criticised as inadequate: later he employed a heavier pressure for the fine 32 ft. reed at Lincoln Cathedral. Reeds of this pitch are usually labelled "contra trombone" or "contra bombarde."

A 64 ft. pedal reed, labelled "contra trombone," occurs in the Hill organ of Sydney Town Hall. It has wooden tubes and is the only example in existence.

The extra large tongues of 32 ft. reeds are sluggish in starting, unless helped by some pneumatic device attached to the boot. The weighted portion of the tongue is connected by a tapped wire to a pneumatic motor, which may be either outside or inside the boot, and this motor is inflated by the wind entering the boot. Single motors with a spring for ensuring a smart return, or a double-acting motor system, may be employed.

Other types of pedal reed in 16 ft. pitch are sometimes introduced as independent ranks into the pedal organ for the purpose of providing special tones. Such are the clarinet and the krummhorn, 16 ft., with half-length cylindrical tubes of fairly wide scaling and capped at the top. The dulzian, 16 ft. is a curious reed possessing small-scaled conical tubes and giving a tone which is a cross between a fagotto and an oboe.

All pedal reeds can be extended up to provide their 8 ft. and 4 ft. octaves, being then labelled clarion if of the chorus type.

III. **DIAPHONES.** The diaphonic principle has been explained in Chapter I and reference made to the drawings of three types in Plate V. Mr. Compton has presented us with many fine examples in his instruments, giving the effects of bourdon, violone and reed tone of varying power. In the totally enclosed organ the diaphonic mechanism and pipe on heavy pressure can produce very penetrating tones which successfully overcome the damping influence of the chamber, and the pipes can be so constructed with "Haskell resonators" as to demand the minimum of height. Nevertheless, the diaphone has never attained any degree of popularity with the generality of builders who have preferred to stick to the flue and reed pipe for the provision of pedal tones.

IV. **MIXTURES.** A pedal scheme is not by many considered complete without at least one mixture consisting of flue pipes sounding octaves and mutations. Lynnwood Farnam, to mention one whose name carries weight in connection with tonal matters, strongly objected to mutation ranks in the lowest octave of the manual because when coupled to the pedal they upset the melodic outline of the pedal bass part. I agree; but the remedy surely is not to eliminate the mutation ranks but to treat them so as to make their tone fit in with the octave ranks without the least trace of peakiness. Thus, the mutations can be regulated with due regard to their effect in the successive octaves of the pedal compass, their strength being gradually increased during the ascent from the middle note of the pedalboard. In any case, no pedal mixture is likely to be a success unless it is most carefully voiced and regulated in each of its ranks by a thoroughly competent artist. Let us suppose that we are designing a pedal scheme comprising open, 16 ft., bourdon, 16 ft., quint, 10⅔ ft., octave, 8 ft., flute, 8 ft., flute, 4 ft., and 16, 8 and 4 ft. reeds. It is desired to add a mixture to this. How shall we proceed? We require at least a superoctave 4 ft. and a twenty-second, 2 ft., plus mutations. The latter would presumably be a twelfth, 5⅓ ft., a tierce, 3-1/5 ft. and a larigot (nineteenth), 2⅔ ft. Our mixture will then consist of 12, 15, 17, 19, 22; and if we add the independent quint, 10⅔ ft. and octave, 8 ft., we get the series 5, 8, 12, 15, 17, 19, 22 on top of the 16 ft. tone. Vierne, the celebrated French organist and composer, was very partial to the flat septième, so that doubtless he would have us add the flat 21st to the above. This would give us nine ranks of "harmonics" on the pedal. The octave ranks will be diapasons suitably treated and regulated. The quints will be stopped flutes. The tierce

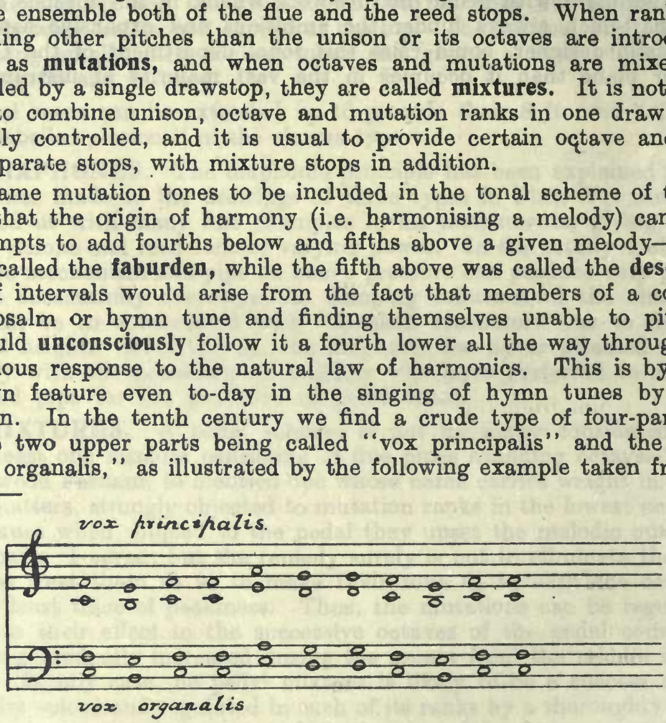
(17th) may be either a stopped metal flute or a dulciana. The septième rank would require very careful treatment, and a stopped pipe seems indicated if the tierce is of open metal: or vice versa. It would be a simple matter to regulate the strength of each rank so that in the lower half of the pedal compass the mutations are not unduly prominent, while in the upper half they gradually grow in intensity and volume. The substitution of open metal pipes for stopped wood or metal could be effected in the top octave, if desired: the scaling being on geigen lines for preference. Even so, it would be better to retain the stopped pipe for the septième throughout the compass, or else for the tierce if the septième is a dulciana. A "sharp mixture" comprising 24, 26, 29 can also be added, with suitable treatment and voicing of diapason and dulciana pipes. There is ample scope for experiment with pedal mixture-work which, in the absence of financial considerations which always hinder the ambitious and expansive aspirations of the enthusiastic designer, could raise this tonal department of the Organ to a much higher plane than it occupies in the vast majority of instruments even to-day.

CHAPTER VII

Octaves and Mutations

AT the opposite end of the tonal spectrum we have what is called **the upper work** of the Organ, which, broadly speaking, adds brilliance and vivacity to the ensemble both of the flue and the reed stops. When ranks of pipes sounding other pitches than the unison or its octaves are introduced they are known as **mutations,** and when octaves and mutations are mixed together and controlled by a single drawstop, they are called **mixtures.** It is not necessary, of course, to combine unison, octave and mutation ranks in one draw: they can be separately controlled, and it is usual to provide certain octave and mutation ranks as separate stops, with mixture stops in addition.

How came mutation tones to be included in the tonal scheme of the Organ? We know that the origin of harmony (i.e. harmonising a melody) can be traced to the attempts to add fourths below and fifths above a given melody—the fourth below was called the **faburden,** while the fifth above was called the **descant.** This grouping of intervals would arise from the fact that members of a congregation singing a psalm or hymn tune and finding themselves unable to pitch on the melody would **unconsciously** follow it a fourth lower all the way through, perhaps in unconscious response to the natural law of harmonics. This is by no means an unknown feature even to-day in the singing of hymn tunes by a modern congregation. In the tenth century we find a crude type of four-part harmony in use, the two upper parts being called "vox principalis" and the two lower parts "vox organalis," as illustrated by the following example taken from **Musica Enchiridis:**—



The treble stave represents the voice part and the bass stave the organ accompaniment, and if we omit the lower part of the **vox organalis** we get Guido's **diaphony** or **organum.** This primitive note-grouping may quite conceivably have inspired the early organ maker to provide mutation ranks and thus create what we now call the "mixture":* in fact, the tenth century organ was nothing but a mixture, there being no drawstops and no chord-playing; for the organist had to "beat" the keys with his closed fist and could therefore only produce one note at a time. It must also be borne in mind that such staccato playing would tend to obfuscate the mutational dissonance which had been introduced into the cleaner unison and octave tones, and with very little skill the organ builder could achieve a cohesion of parts resulting in a bell-like effect. It was a different matter when legato playing became possible with the introduction of a lighter key touch; and yet as the mechanical structure of the Organ evolved and opened the door to ever-increasing possibilities of development, the mixture was not discarded: far otherwise, it grew to almost inordinate proportions in the tonal schemes of the sixteenth and seventeenth centuries on the Continent. This is understandable in view of the light wind pressures and the still crude mechanism available: it was not possible under such conditions to increase the power and effectiveness of the Organ save by the addition of many ranks of high-pitched pipes. The introduction of diapasons of greater power and of heavy pressure chorus reeds has not, however, ousted the mixture from the organ specifications of to-day, though Robert Hope-Jones did attempt to prove that it is an unnecessary appendage to the tonal scheme. The obstinacy with which the mixture has resisted all such attempts to eliminate it is amazing in view of its undoubted unpopularity with a very large number of organists and purchasers of organs. If a census were taken of the views of organists, in particular, on this question it would reveal the fact that the majority either dislike or apathetically accept the inclusion of **mutation ranks** in an organ scheme. In the opinion of those who know there has never been a greater teacher of organ playing than the late Sir Walter Parratt, yet in the second edition of Grove's Dictionary he committed himself to the following dictum: "mixtures can properly be used only to accompany congregational singing." I listened to Sir Walter Parratt expounding Bach on the fine Willis organ in New College Chapel, Oxford, in 1904: he never once used a mixture or a mutation. The late Thomas Cawthra, who was organist of St. Barthólomew's, Armley, till death removed him from this post, was tremendously proud of his mixtures, as indeed he might well have been; yet at a Sunday evening service which I attended he never once drew a single mixture or mutation till at the end of his concluding voluntary he added the great five-rank mixture in the final crashing chord. If mutations are an essential ingredient in the tonal edifice of the Organ how is it that the average organist fights shy of them? There are exceptions, of course. Sir Edward Bairstow at York Minster used the mixtures and mutations frequently. At one memorable Evensong at which I was present he made special use of the great organ mixtures with striking effect. He knew how to use them. After the service he told me he wished me to hear how cleverly Arthur Harrison had treated and voiced these particular ranks of pipes at his personal request. There are far too many organists who disdain to draw a mixture stop except in combination with the chorus reeds on swell or great: as one quite famous recitalist confided to me, "I never draw the mixtures unless they can be covered up by the more powerful reeds." Thousands of church organists never use any stop-combination containing tones above 4 ft. in pitch, the sole possible exception being the "full swell" which includes the usual mixture **on the piston or combination pedal.** Can we be surprised that organ committees—and even some organ builders—regard mixture stops as a waste of money and material?

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* The opposite view is held by many as to the origin of the organum, namely that the vocal descant and faburden were inspired by an attempt to imitate the organ mixture. Historical evidence is insufficient to support either hypothesis. The human voice is many centuries older than the organ pipe, and it is at least reasonable to suggest that first the vocalist (!) and then the organ builder introduced the quint effect in unconscious though crude imitation of nature's law of harmonic development.

The real reason for this apathy is that there are far too few really satisfactory examples of the mixture to be found in English organs. Mixtures have a bad reputation. They either "scream" or else they "tickle like a feather." The problem is always to know how to steer between the scylla of excessive brilliance and the charybdis of excessive coyness.

It has been stated time and again that organ pipes are deficient in natural harmonics and that therefore it is necessary to atone for this deficiency by adding artificial harmonics. We know that the trumpet and trompette are by no means deficient in harmonics, nor are the string-toned stops: it cannot be that these tones need harmonic reinforcement.* But what of the diapasons? Dr. Boner's analyses show that this class of tone is characterised by harmonics up to the eighteenth; so why attempt to reinforce the natural harmonics of the diapason? Hope-Jones was of the opinion that the only reinforcement needed was obtainable by means of such tones as the octave, the quintadena, tiercina (sounding the seventeenth along with the prime) and the strings and reeds (e.g. his "double English horn," which emitted a thin blare). He could not see why the ancient tradition of building up organ tone with a series of artificial harmonics should be any longer tolerated by modern ears. Now it is of supreme importance that we should try to distinguish between what we as individuals think the listener to an organ ought to hear and what constitutes organ tone at its best and highest. The *argumentum ad traditionem* by itself is unconvincing if a certain scheme of tonal architecture produces effects that nine listeners out of ten regard as unmusical or offensive: the argument must be backed by something more than mere tradition. Can we adduce that something more in support of mixtures? The error that Hope-Jones—and his followers—made was to debase the "chromotonic mean" of the organ as a musical instrument: the mean tone-level of the sound-picture was too low, and the result was a drabness which weighed down the listener's soul. Imagine an organist playing the whole of the musical accompaniment of a church service on a double (16 ft.) and a unison (8 ft.) only—no octaves above the unison being added at any time: we should be crying out for the removal of the double-pitched stop at least. But unisonal sounds unrelieved by other pitches soon become intolerably wearisome. The need for octave extension is strongly felt. Yet excessive brilliance—top-heaviness—is just as irritating as excessive drabness or that "muddy effect" produced by the lower-pitched combinations. **In all cases where music is produced by sustained tones the human ear demands pitch-changes and is never satisfied with unisonal sounds only.** Octave tones let in the light and lend vivacity to the whole. They raise the mean pitch-level—the chromotonic mean—of the tonal spectrum to a sane normality, so that it is neither too low nor too high. The addition of octave ranks of pipes was due to the instinctive desire of musical man for this artistic placing of the chromotonic mean. As the volume of tone was increased so the need for pitch-extension became more and more urgent—a need that Hope-Jones failed to realise and to supply.

It is not difficult to find ample justification for the use of octaves and super-octaves as an integral part of the tonal scheme of the Organ; nor should it be more difficult to convince the unbiassed organ-lover on logical grounds of the appropriateness of suboctave tones as equally deserving of recognition. It is when the tonal architect insists on adding **mutation** tones that arguments appear to rest more on a personal than a logical basis. For why should off-unison ranks be deemed essential, and what purpose do they serve? Unfortunately, the attempts made by writers of organ books in the past to justify the existence of mutations have not been as convincing as they might have been. Reference to the diaphony of the tenth century is not calculated to impress the modern organist, nor is there the slightest reason why he should be expected to yield respect to classic tradition for its own sake. He can only be convinced by a **demonstration.** This is a scientific age, and people demand positive proof rather than verbal argument. "Let the organ builders themselves produce mixtures and mutations that we can listen to with enjoyment," is the demand: "their arguments can come later."

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* The introduction of viol mixtures seems to disprove this harmonic corroboration theory, as well as the quint coupler. Even reed mixtures have been added to a reed chorus, as, for example, in the "harmonic division" of the organ in the Cadet Chapel at West Point, U.S.A.

It is necessary, however, to add that even if the organ builder does produce the ideal mixture the player must be able to make a proper use of the effect, so that the task of convincing the listener devolves on both the maker and the player of organs. The subject of the effective handling of the upper-work of the Organ by the performer is not one to be dealt with in this book which is concerned primarily with the construction of the Organ. We are bound, however, to try to justify the existence of mutations without reference to traditional or personal sentiment, and since it **is** possible to provide a concrete demonstration of their effectiveness, given the right instrument and the right player on that instrument, there must be a solid reason for that effectiveness. In short, **if properly treated mutation ranks were removed they would be missed:** there would be a sense of loss. **What** would be missed? That is the point! Cohesion between the various ranks, unisonal and octaval? No. It is quite possible to bind the various octave ranks together to form a cohesive whole. Brilliance of effect? No: for this can be obtained by means of powerfully voiced octave and superoctave ranks and also (if need be) by the addition of fiery-toned chorus reeds. Liveliness? Yes. For this is a quality which the mutationless organ as a musical instrument lacks. The Organ cannot be said to possess the kinetic energy of the piano or of any of the "expressive" instruments of the orchestra. The Organ lacks **nervous** flexibility. The so-called "expressive effects" produced by the manipulation of the swell box shutters are artificial and depend for their success on the ability of the performer to delude the ears of the listener—a delusion by no means to be sneered at or depreciated—there is nothing that corresponds to the intimate control of tone-colour that the player of an orchestral instrument has at his disposal. Intimacy of tone-control and nervous flexibility are essential to the personality of the orchestral instrument: they lend life and character to its notes. The Organ, on the contrary, as a musical instrument, being deprived of this particular mode of expression, has to depend for its effectiveness on (1) its intrinsic tonal beauty and (2) the manner in which its tones are handled and interpreted by the player. Perhaps the chief appeal of the Organ as a producer of beautiful sounds lies in its statuesque tonality: yet that which is statuesque is not compelled to be dull or lifeless. The effect of mixture-work is to infuse the tonal picture with light, just as if we were to draw the blinds and let the sun-rays play upon the objects scattered about our living-room. The objects are transformed: the light-rays scintillate and sparkle happily in every crevice and on every surface where they can find their way. Mixture ranks should produce this same effect acoustically: if they do not do this, they are a failure. Mutations fill in the crevices between the octave ranks, **not** in order to bind them together (since the natural harmonics of the octave ranks, if sufficiently developed, can do that), but in order to suffuse the whole with **life.** That this is their true function is proved by Dr. Boner's analysis of a diapason chorus consisting of unison, octave, twelfth, superoctave, plus a three-rank mixture comprising seventeenth, nineteenth, and twenty-second. In this chart the prominent tones are unison, octave, twelfth, seventeenth, nineteenth, twenty-sixth, twenty-ninth, thirty-sixth. The last two tones are **octave** pitches and not mutational—what happens is that the mutations **reinforce the higher octave tones in the series.** This is entirely due to the "summational effect" of the mutations when combined with the lower octave ranks. Thus the addition of mutation tones has the effect of sharpening the upper portion of the spectrum, setting a tonal spire to the top of the tonal tower. It is this that imparts the quality of liveliness to the chorus—the higher tones are reinforced, tones which cannot be produced by organ pipes because such pipes would have to be made to impossibly small dimensions. In addition to this effect, however, mutations produce a harmonic clash in the tonal spectrum which lends life and colour to the chorus. By the phrase, "harmonic clash," I mean a dissonant effect deliberately introduced in appropriate proportion to the whole for the purpose of (a) setting the chromotonic mean at the correct level and (b) removing all trace of insipidity.

In addition to the summation tones resulting from the interlacing of octave and mutation ranks there are also the differential tones which reinforce the lower notes of the chorus. Thus, if a mixture consisting of octave, twelfth, fifteenth, nineteenth and twenty-second be drawn and a chord played on it, the unison tone will appear to be generated even though there is no unison rank drawn. Mr. Thomas Casson related how he had been compelled for lack of time to include the 8 ft. diapason on the great manual of a new organ which he had promised to complete in readiness for the opening ceremony. He had, however, put in a complete diapason chorus of 8, 12, 15, 17, 19, 21, 22 with only a flute to represent unisonal tone. The differential tone produced by this arrangement of ranks was sufficiently pronounced to make the absence of the unison diapason a matter of indifference to the audience. Perhaps the story contains in it the elements of exaggeration, but it is by no means unbelievable. That the unison tone receives some reinforcement is beyond question, but the fact does not seem to be of much importance since the unison tone can always be provided in the form of pipes. The differential effect, however, has proved of some value in connection with the **quint** rank, sounding a fourth below the octave, as the combination of unison, quint and octave undoubtedly produces the effect of a "transparent" double (suboctave) without the "muddy" quality so often associated with 16 ft. manual stops.

It has been urged in support of mutations that their presence is necessary in order to correct the balance of the upper and lower portions of the spectrum: that is, it is claimed that the lower octaves of unison diapason stops need harmonic reinforcement if the balance between lower and upper registers is to be maintained in correct proportion. I find myself unable to assent to this statement if it is meant that the bass and tenor registers are thereby rendered uniform in power and quality with the upper registers. If, however, the idea behind the statement is that octave and mutational **colouring** is desirable in these lower registers for the purpose of extricating from a confused mass of undifferentiated sounds the voice parts of fugal and contrapuntal music, then I must confess to being sympathetically interested in the suggestion. This is as far as I can honestly commit myself in a published expression of opinion, since I have yet to hear a successful example in terms of organ pipes of this particular treatment. My friend, Mr. G. Donald Harrison, definitely claims in a letter to me to have achieved success in this direction, and I am fully prepared to believe it. His contention is that "if mixtures are properly planned and voiced, they point up the unison tone in the more obscure parts of the compass and broaden the treble." Now we know, or can easily discover, that if we draw 8 ft., 4 ft., 2 ft., 1 ft. and 6 in. diapason ranks in combination and play each note from CC of the great manual to tenor B (24 notes), the pipes of the ranks above the 4 ft. rank stand out very prominently unless they are regulated to speak with considerably less power than those of the lower ranks. We feel that we do not want these high-pitched tones forced unduly upon our ears. But in the upper portion of the compass these same ranks can be regulated to sound with far greater vehemence of tone without disturbing our sense of melodic proportion. They may be too shrill in actual quality but there will be no upset of pitch-balance as such—the top line will stand out independently of the lower accompanimental register: there will be no interference from below. If, however, the lower register is reinforced with shrill-sounding, high-pitched ranks, these will impose their tones on the melodic line of the treble parts and the result will be a melodic muddle. Mutation tones introduced in the lower compass are more readily distinguishable as off-unisonal unless they are sufficiently suppressed so as to become **timbre-**producers only. In short, the introduction of high-pitched octave and mutation ranks in the bass and tenor registers may very easily divert the attention of the listener to the pipes and away from the musical texture of a polyphonic composition. This has been my own unfortunate experience, so that I can speak feelingly. It would seem, therefore, that the only solution of the problem of balancing the registers by means of mixtures, if attempted at all, is to treat the various ranks so that they conform in type to something between what is generally regarded as "the chorus mixture" and the "synthetic mixture." The object in view must be not brilliance so much as clarity of outline. The designer and voicer must apply the photographer's art of "touching up" the parts where required. This involves a very intricate and elaborate scheming of pipe-work. And I may add that differential and summational tones play a vital part in the result. Mr. Harrison likes, for instance, to avoid placing the pipes so that their mouths lie on the same plane: for this purpose he varies the lengths of the pipe-feet. The breaks are also very skilfully arranged as well as the relative strengths of the various ranks in each zone of the compass and between the breaks. The unison rank is artistically subordinated to fit into the mixture scheme and in some designs the open diapason is dispensed with altogether in favour of appropriately voiced stopped or half-stopped pipes. Thus, in the Worcester Art Museum (Mass.) "Bach organ" (built by the Aeolian-Skinner Organ Company) the great manual consists of quintaton, 16 ft., bourdon, 8 ft., principal, 4 ft., rohrflöte, 4 ft. and fourniture (III to V ranks); while the "recit" manual (or episodic division) has rohrflöte, 8 ft., prestant, 4 ft., cromorne, 8 ft. and cymbel (IV ranks). (The full specification is given in chapter IX).

So much for the useful part played by mixtures in the interpretation of polyphonic organ music. They are, however, also of service in the rendering of other styles of composition. My friend, Mr. H. A. Frampton, of Kidderminster, who in my opinion stands in the very front rank of organ recitalists and is one of the very few able to display the resources of the modern organ to the greatest advantage, states that mixtures, appropriately designed and voiced, are absolutely essential to the efficient interpretation of the modern French romantic style of organ music, a statement with which I cordially agree.

Mixtures may be classified into

1. Diapason mixtures;
2. Mixed types;
3. Dulciana mixtures;
4. Viol mixtures;
5. Flute mixtures or synthetics.

I propose to deal with each type in turn.

1. **Diapason Mixtures.**—These are the classic type and are composed of diapason pipes of varied strength and quality. The mixtures of the old builders were inclined to flutiness owing to the obtuse form of languid bevel employed. Lightly blown diapason pipes tend to blend with each other more happily than the modern type, and the old "cornet" consisting of unison, octave, twelfth, superoctave and tierce, was composed of large-scaled diapason pipes, though often the unison rank was a stopped pipe. This combination produced a synthetic effect and was much used for giving out the melody of a tune by the church organists of those days. The French cornet was similarly designed. The Silbermanns also produced fluty mixture-work (as compared with that of Schulze, Father Willis or Cavaillé-Coll): they depended for brilliance of effect on the number of ranks and the high pitches employed. The pipes were on low pressure and had low, wide mouths. Schnitger made his mixture pipes even more fluty than Silbermann, and relied on a wealth of softly voiced high-pitched ranks for brilliance. Later the ranks were given an increased harmonic development, notably by Walcker, Schulze, Cavaillé-Coll, Willis, and others. This increased harmonic development led to fewer mixture stops being introduced than used to be customary in the days of lightly blown diapason choruses composed of ranks of much the same strength and often of much the same scaling. In far too many cases the mixture was represented by a set of high-pitched diapason pipes which refused to blend with the rest of the chorus and came to be known as "the screaming apparatus." A terrible disservice was done to the organ mixture by such travesties of tone: organists have not even yet recovered from the ill effects of inartistically treated upperwork. Moreover, it has to be remembered that some of us are more sensitive to high-pitched sounds than others, that what is a "lovely brilliance" to one man is a "fierce din" to another. To the mixture-hater the various names given to various types of diapason mixture are so much nonsense. The names indeed are many: grave mixture, quint mixture, full mixture, plein jeu; sesquialtera; cornet, mounted cornet; sharp mixture, acuta, furniture; cymbal; compensating mixture; carillon; harmonics. Of these I single out (1) the **grave mixture** or quartane, consisting of two ranks only, namely twelfth and fifteenth (German, **rauschquint**); (2) the **quint mixture,** consisting of unison, fifth, octave, twelfth and fifteenth; (3) the **cymbal,** consisting of the higher-pitched ranks up to the thirty-eighth, e.g. 31, 33, 38, or 29, 33, 36, breaking to an octave lower at each successive octave till at the top octave it becomes 3, 5, 10, or 1, 5, 8. (There are, however, various ways of arranging the ranks and their successive breaks). (4) The **sesquialtera,** originally a two-rank mixture consisting of twelfth and seventeenth (tierce), but frequently any mixture containing the tierce but not the septime. In many organs the tierce was not carried up beyond the first or second octave from CC. (5) The **full mixture,** consisting of 12, 15, 19, 22, 26, 29 and breaking two or more times in the course of its upward career. (6) **Harmonics,** a mixture in which the complete harmonic series up to the twenty-second is artificially reproduced.

It will be understood that the above arrangements of ranks are composed entirely of diapason pipes of varying scales and strengths. Other types of flue pipe could, of course, be introduced for all or any of the ranks, but we shall be considering this form of treatment in the next category.

The subject of "breaks" needs some more detailed explanation. There being a practical limit to the speaking-length of an organ pipe, it is obviously impossible to carry up such a rank as the twenty-second (to say nothing of higher-pitched ranks) to the sixty-first note of the manual (top C). Actually, it is not considered feasible to complete any rank higher than the fifteenth. The problem is therefore supposed to be solved by taking the higher-pitched ranks as far up the compass as possible and then continuing them upward in suboctave pitch: thus, a nineteenth becomes a twelfth, a twenty-second a fifteenth, a twenty-sixth a nineteenth, a twenty-ninth a twenty-second. Very often the rank is not carried up to the limit of its pitch but is broken at a somewhat earlier point in the compass; and again, when broken, it may change to a note two octaves instead of one octave lower. As an example of the method I give the following composition of a "full mixture":—

CC to BB,	15	19	22	26	29
Tenor C to mid. F,	8	12	15	19	22
Mid. F sharp to treb. D,	1	5	8	12	15
Treb. D sharp to top C,	½	1	5	8	12

If the twelfth and fifteenth are arranged as separate stops, we have left a mixture consisting of

CC to BB,	19	22	26	29
Tenor C to mid. F,	8	19	22	—
Mid F sharp to treb. D,	1	5	8	—
Treb. D sharp to top C,	½	1	5	8

Thus, the removal of the twelfth and fifteenth from the five-rank mixture does not leave a three-rank mixture but a **four**-rank mixture for the lowest and highest octaves of the manual compass, with a three-rank mixture for the intervening octaves. It is assumed, however, that the twelfth and fifteenth would always be drawn with the rest of the mixture ranks. With regard to the breaking of a rank to a pitch two octaves lower instead of one, this would occur in the case of a mixture designed to function independently of the separate twelfth and fifteenth stops. Thus, the five-rank full mixture above illustrated would, if it retained the twelfth and fifteenth ranks, have the following composition:—

	Full mixture.					Separate stops.
CC to BB,	15	19	22	26	29	1, 8, 12, 15
Tenor C to mid. F,	1	5	8	19	22	1, 8, 12, 15
Mid F sharp to treb. D,	1	5	8	12	15	1, 8, 12, 15
Treb. D sharp to top C,	½	2½	1	5	8	1, 8, 12, 15

The above arrangement is based on two main rules: (1) there must not be two mutations to one octave (or unison), and (2) there must not be two higher mutation ranks of the same pitch to one of lower pitch. Thus, if we break the 15, 19, 22, 26, 29 at tenor C to 8, 12, 15, 19, 22 (each rank falling an octave), we get in conjunction with the open diapason, 8 ft., principal, 4 ft., twelfth, 2⅔ ft. and fifteenth, 2 ft. (i.e. 1, 8, 12, 15), the following series:—

Tenor C to mid. F, ... 1 8 8 12 12 15 15 19 22

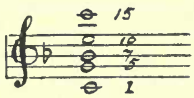
which gives two principals to one unison diapason, and two twelfths and fifteenths to one unison. If we alter the second rank from octave to unison (making 1, 1, 8, 12, 12, 15, 15, 19, 22) we get two 12ths and 15ths to one octave. The only way to get the right proportion is to break the 15, 19, 22 of the CC to BB portion down two octaves, making them 1, 5, 8 from tenor C to treble D: then the two remaining ranks (26 and 29) can be made to break down one octave at each successive change. Another glance at the specification of this mixture will show that this has been done. The "½" and the "2½" represent the double (or octave below the unison) and the sub-quint (or octave below the fifth) respectively. The ranks in the mixture stop which duplicate the separate stops (such as the unison, octave, twelfth and fifteenth) would not be voiced as exact replicas of each other, but would be given suitable treatment and voicing to avoid "vain repetition" and consequent "drawing" effect (the organ builder's term for mutual interference). And here we come to the question of introducing a mixed characteristic into the treatment of mixture ranks.

2. **Mixed types.** Should every rank of a mixture be a diapason? This is a question that has exercised the minds of voicers the world over. It is held by many that the unison and octave ranks **should** be diapasons, but the mutation ranks should not be diapasons but flutes, or at any rate be modified in tone as well as in power in relation to the octaves. A compromise has been attempted by making the mutation ranks diapasons with fifth mouths (in width) while the octave ranks are given wide mouths such as a quarter or two-sevenths. This is doubtless a good idea especially commendable when it is desired to plan a bold mixture scheme for a resonant building. Flute-toned mutations are liable to defeat the object of their existence and be engulfed by the more dominant tones of the octave-work; but they certainly solve the problem of "screaminess" if the octave ranks are regulated in due proportion. In actual practice, the treatment of the mutation ranks depends to a large extent on the type of building in which the organ is situated and the type of mixture selected by the designer. For instance, let us suppose that it is intended to incorporate a mixture labelled "harmonics, V ranks" in a great manual scheme for a building of moderate resonance. The ranks would comprise 15, 17, 19, ♭21, 22 (which when sounded together would give the chord of the dominant seventh (C-E-G-B♭-C). The 15th and 22nd would be diapasons extending more or less the character of the open diapason, 8 ft. and principal, 4 ft. The 19th (or octave 12th) could be a diapason with a fifth mouth cut up a fourth of its diameter and voiced to speak a little more softly than the 15th. The 17th (tierce) is an awkward rank to deal with, as it is apt to upset the cohesion of the ranks so far treated successfully. This is mainly due to the dissonant intervals resulting from the modern system of "equal temperament" tuning, the major thirds of the keyboard being more noticeably dissonant than the fourths and fifths. Since the third or tierce of the mixture is tuned perfect, the clash between the tempered thirds and the mutational third is unavoidable, and if the tierce is made too prominent the effect is none too pleasant. It might be supposed that the tierce could be tuned to the equal temperament as well as the keyboard thirds, but this only produces a different kind of dissonance which is just as objectionable. It seems best, therefore, to keep the strength of the tierce relatively weak, voicing it as a dulciana or a flute. The exact strength can only be determined **in the actual building.** The flat 21st (septime) is not so difficult to treat as the tierce. For this rank stopped metal pipes seem best from CC to the point at which it breaks into a flat 14th, when it may be changed into an open metal flute or a fluty gemshorn. If after this it breaks into a flat seventh, dolce pipes are recommended.

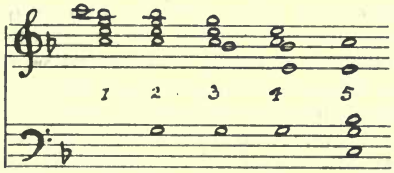
The following is the suggested composition of the "harmonics, V ranks":—

CC to BB, ...	15	17	19	21	22
T. C to T. G, ...	5	15	17	19	21
T. G sharp to mid. A sharp.	5	14	15	17	19
Mid. B to treb. B, ...	5	10	14	15	17
Top octave, ...	1	5	7	10	15

The absence of the twelfth will be noticed. This rank has a separate existence in the manual stop-list, so need not be repeated. There will also be a separate fifteenth, and the rule forbidding two fifteenths to one octave (principal, 4 ft.) is broken. But the tierce and septime require the "cover" of the fifteenth in the mixture itself, this particular fifteenth being voiced to give less power and brilliance than the separate fifteenth, which need not necessarily be drawn when the mixture is used. It will be noted that there is a quint (5⅓ ft.) rank from tenor C to the top note—a very valuable asset in a mixture of this kind, giving solid support to the upper ranks and helping to bind the whole mixture to the unison and octave stops of the manual. It is best made of stopped metal pipes, with either plain wooden stoppers or metal canisters, as preferred. A point of interest in connection with the above scheme of breaks is that only one rank is broken in succession in the first three steps, the object of this arrangement being to disguise the breaks as far as possible by the minimum of change at each step. At the first step the 22nd is changed to a **fifth** and not to any suboctave pitch: at the second step the 21st is changed to a 14th: at the third step the 19th is changed to a **tenth** and not to any suboctave pitch: at the fourth step the 17th is changed to a **unison** and the 14th to a seventh. In this last step there are two changes because **it is necessary to separate these lower pitched ranks sufficiently to prevent a gritty effect,** the chord of harmonics being built up thus:—



Theoretically one may suppose that the 22nd would break to an octave, the 19th to a fifth, the 21st to a 14th, and the 17th to a tenth; but in art rules are made, first to be learnt and assimilated, then to be broken when circumstances suggest that a breach is better than the observance. The breaks in the five-rank mixture above illustrated are distinctly "unorthodox" according to the Casson formula, but they distribute the various tones throughout the manual compass in such a manner as to ensure a reasonably uniform harmonic reinforcement. The grouping of the harmonic changes is presented in the following series of chords:—



It is thought by some that certain of the unison and octave ranks in the diapason chorus might be made stringy in order to accentuate their tones where such accentuation is deemed desirable, but string tone is not conducive to uniformity of diapason character and should be avoided. No harmonic development beyond that of the geigen is really suitable for any of the ranks comprising the main flue chorus.

The placing of the breaks is a matter of personal choice. It is now considered bad to break at each successive C of the manual compass; the changes occur more appropriately at irregular intervals, though not necessarily at the points indicated above. It is advisable to avoid carrying up a series of ranks with a mutation other than the fifth-speaking rank at the top for a distance of more than an octave, especially if the said mutation is of high pitch. Thus, the flat 21st only heads the first break from tenor C to the G above (eight notes), and the tierce heads the third break for an octave (middle B to treble B).

3. **Dulciana Mixture.** Although he did not introduce this variety of mixture, one almost unconsciously associates the name of George Ashdown Audsley with it, since he incorporated a beautiful example in his chamber organ at Richmond where he once lived before he migrated to America. Several copies of this have since been made by various builders, some of which I have heard, though none have been as successful as the original. The probable reason for the difference of effect is in the pressure of wind employed, Audsley having used only 2⅜ in. Dulciana pipes **lightly blown** are essential to success for this particular type of mixture, and the scale for pipes above the six-inch C pipe is increased somewhat. Thus, if we adopt a scale of 2 in. at the 4 ft. pipe, it is necessary to increase the scale to 2½ in. **as at the 4 ft. pipe** when the 6 in. pipe is reached: this means that instead of the 6 in. pipe being 7/16 in. it will be 9/16 in. The mouths will be a fifth of the circumference in width for every pipe. The composition of Dr. Audsley's mixture was 19, 22, 24, 26, 29 at CC: it eventually became 1, 8, 10, 12, 15 from treble C to top note.

4. **Viol Mixture.** This is, as its name implies, composed of string-toned pipes of the viol class, though, like the Dulciana Mixture, the scaling is increased for the higher-pitched pipes. The best example I ever heard was the **cornet de violes** by Mr. Henry Willis which he placed in the solo division of the (now destroyed) organ in the Colston Hall, Bristol. This consisted of three ranks, 12, 15, 17 at CC; then of four ranks, 8, 12, 15, 17 at tenor G; and lastly of five ranks, 1, 8, 12, 15, 17 from treble F sharp to top. There are no breaks, but additions, during the ascent. The pipes were noticeably softer than the other members of the string family in the same division. This is as it should be, since the high development of harmonics alone is sufficient to give keenness to a family of viols from 16 ft. to 4 ft. The addition of still higher-pitched viol pipes and of mutations voiced to produce string tone needs very careful voicing and regulation of each rank to prevent undue brilliance. Several examples which have come under my notice give far too cutting a tone when played in chords: this can be avoided by skilful and artistic treatment. The idea of adding extra ranks at the nether end as instanced above is an excellent one, and is typical of the modern cornet, whether pipes of diapason tone or string tone are employed.

5. **Flute Mixtures.** These are designed as "timbre-creators," that is, the ranks are intended to imitate nature's harmonics in tone and general composition. It is therefore necessary to discourage harmonics within the tone of the rank itself, so that flutes, stopped or open, are employed for the purpose. The same process is adopted by makers of electronic instruments in which the pure sine waves produced by electrostatic or electrodynamic means are built up into tone-qualities imitative of organ stops. It is a simple matter to reproduce as closely as possible the various harmonics shown in Dr. Boner's analytical charts for various organ tones by means of non-harmonic units of tone. Although it is impossible to reproduce the complete series of natural harmonics, let alone the formant frequencies, a passable copy can be made with a sufficiently close resemblance to the original to enable the listener to recognise the basic characteristic. In the case of the electronic imitation a loudspeaker is necessary in order that the electrical sound-patterns may be converted to sound-wave patterns in the air; but synthetic reproductions of tones by means of organ pipes need only the human ear to interpret them, and Mr. John Compton has many ingenious

examples to his credit. I single out, from a number of instances, the synthetic pedal 32 ft. "baryphone" at Downside Abbey, and the synthetic pedal 16 ft. "cornet" at the B.B.C. studio at Maida Vale. These latter are built up of stopped pipes of varying scales and treatment so as to produce a composite tone-quality resembling a reed. It is a simple matter to reproduce the organ clarinet **up to a point** by compounding three or four ranks of stopped pipes sounding unison (strong), twelfth (less strong), tierce (weaker still), and septime (very weak indeed). A three-rank mixture consisting of 4 ft. zauberflöte, stopped twelfth and dulciana tierce makes a synthetic cor anglais: a synthetic viola can be produced by an eight-rank mixture of stopped metal pipes comprising unison (50 per cent), octave (100 per cent.), twelfth (33 per cent.) fifteenth (60 per cent.), tierce (55 per cent.), nineteenth (15 per cent.), septime (10 per cent.), twenty-second (45 per cent.). A pedal violone can likewise be synthesised by means of stopped wood pipes. A synthetic trumpet (of sorts!) can be made up of unison (50 per cent.), octave (100 per cent.), twelfth (100 per cent.), fifteenth (75 per cent.), tierce (65 per cent.), nineteenth (75 per cent.), septime (75 per cent.), twenty-second (40 per cent.)—eight ranks of large-scaled metal canister-stopped pipes being required. A tromba would consist of unison (100 per cent.), octave (100 per cent.), twelfth (90 per cent.), fifteenth (50 per cent.), tierce (90 per cent.), nineteenth (75 per cent.), septime (80 per cent.), twenty-second (75 per cent.). These artificial ranks would be tuned perfect, that is free from beats with the unison, whereas the natural harmonics are not in perfect tune, having to be accommodated within the main vibrating wave-system of the pipe (or the orchestral instrument). I have not heard an example of a synthetic tone-compound deliberately mistuned in imitation of nature's product, but cannot see why the result should not be any the worse for it. The difficulty would be to know how far to mistune and which ranks to keep in tune with the unison. The ranks farthest from the unison in pitch would, if nature be followed, be more out of tune than those immediately above the unison.

There is a divergence of opinion as to whether the fifth-sounding ranks (quint, twelfth, nineteenth, twenty-sixth, etc.) should be tuned perfect or tempered. I have tried both systems of tuning with equally good (or bad?) results, so keep an open mind on the subject. Mutation ranks borrowed from unit stops in the extension system of tonal design are bound to be tempered, and I am not aware that the fact of their being tempered, with the exception of the tierce, in any way tells against them. The natural harmonics of organ pipes are supposed to be in tune with the tempered scale, since if the fundamental tone is tuned to the equal temperament the overtones must follow suit; but this is not so with every harmonic—in fact, certain harmonics are almost dead in tune with the artificial harmonics of the mixture if the latter are tuned perfect. The inevitable conclusion is that it simply does not matter whether the artificial harmonics are tuned to the equal tempered scale or tuned perfect: **in any case there is the harmonic clash, and the prevailing notes of the organist's chord determine the nett result.**

One thing is abundantly clear: the whole subject of mixture treatment and voicing is yet in its infancy. Mr. G. Donald Harrison (of the Aeolian-Skinner Company, U.S.A.) is taking great pains to develop mixture-work to its furthest possible limit in terms of the organ flue pipe: Willis, Harrison, Norman, Thynne, Compton, and others in this country have each in their own way contributed specially designed and carefully voiced mixtures, and still the work goes on. Undoubtedly, of all organ stops the mixture is the most difficult to produce with success, whether enclosed or not enclosed. I am, however, able to single out one outstanding example in this country of an organ containing mixture-work on the grand scale which in many respects almost reaches the ideal: that organ is the Schulze masterpiece in Doncaster Parish Church. If the object of mixtures is to create a magnificent blaze of tone without the least suspicion of screaminess or dissonance, that object has been attained at Doncaster by the much criticised Edmund Schulze. This enthusiastic artist, so the late Jeremiah Rogers related, spent three whole weeks finishing and regulating the various mixtures of this organ, working from the early hours of the morning to midnight and sleeping on the bellows for a few hours before resuming his labours. And it should be added that he told Jeremiah Rogers that of all the organ work he had to do the finishing of the mixtures gave him the greatest enjoyment.

CHAPTER VIII

Orchestral and Imitative Tones

ORGAN builders have exercised their ingenuity in imitating the tones of orchestral instruments, though not, I fear, with unqualified success. But does it really matter whether the tone-quality of a rival instrument is actually reproduced or not by the organ pipe? Supposing complete success is achieved: supposing the clarinet, oboe, horn, trumpet, or any other instrument of the orchestra could be reproduced exactly, **it could not be played by the organist's fingers as it is blown by the clarinettist, oboist, horn player or trumpeter**; nor could any organ violin stop be bowed or plucked. The point, however, that we must not miss is that organ builders have been inspired by the tones of these and other instruments to develop in terms of the organ pipe **new** qualities which do definitely produce a musical result and materially add to the resources of an organ. What can be more beautiful than a well-voiced clarinet stop, or violoncello, or flauto traverso, or French horn, or orchestral oboe? I mention the violoncello, but this belongs to the "organ string" category and not to the imitative section, since its prototype is not a wind instrument. I propose, therefore, in this chapter to describe some of the imitative stops of the Organ which have been inspired by the tones of wind-blown orchestral instruments.

1. FLUE PIPES.

The **Vienna Flute** (see Plate II K) is in reality a wooden flauto traverso of small scale with an inverted mouth, the upper lip being rounded so as to produce a semi-circular mouth. Most examples are blown to speak the octave, though the node-hole is often omitted: others, however, speak the fundamental note. The top of the cap is either raised above the block or else made to slope towards the cap (either half-way over or just under). The wooden **flauto traverso** of Schulze in the organs at Doncaster and Tyne Dock is cylindrical in shape, being bored out of the solid: the mouth is a slit cut in the pipe and the block a cork bung. The quality of these flutes is particularly beautiful, quite distinct from that of the metal pipe.

The Haskell **Oboe** is another wood stop and is shown at M in Plate II. The mouth is inverted and kept very low with a roller-bridge to preserve the fundamental. What is not shown in the drawing is the reduction in cross-section of the pipe-body in **depth** (from back to front) commencing at a distance of halfway up the body. Thus the middle C pipe measures $\frac{7}{8}$ in. square for the first twelve inches from the mouth-line, and is then **curved** along the front panel till at the top the cross-section is reduced to 11/16 in. The block, it will be noticed, is of the "sunk" type, at middle C it sinks to a level of $\frac{3}{8}$ in. below the lower lip line. The upper lip is filed to a sharp edge so as to give it a **front bevel.** The height of the mouth is a fraction over $\frac{1}{8}$ in. The cap is first made too long, so that its top edge overlaps the upper lip edge by about $\frac{1}{8}$ in., and is then cut away and sloped on the outside with ears each side so as to provide a support for the roller-bridge. The flue-space is quite narrow, about 1/32 in. There is no notching on the cap, but the block-face has 27 vertical nicks (on the two-foot pipe). The pipe is lightly blown on low pressure.

The Haskell **Saxophone** is constructed very similarly to the oboe, but there are important differences in detail. The scale is nearly double of that of the oboe, being 1-3/16 in. at middle C (2 ft.); the mouth is cut up just over a third of an inch at this C (which is higher in proportion than that of the oboe), and the block is sunk ¾ in. below the level of the lower lip-edge. The body of the pipe is of uniform cross-section from mouth to top. I should mention that neither the oboe nor the saxophone are slotted. Of the two the saxophone is the more successful in imitating its namesake.

2. REED PIPES.

The **Clarinet** is a deservedly popular reed stop. It is fitted with half-length cylindrical tubes as shown in Plate III. Some voicers cap the top of the tube completely and cut a slot just below (as illustrated in the orchestral oboe pipe in the same Plate). Willis invariably—and to my mind rightly—employs an open top with a slide as shown in the drawing. Capped clarinets emit a smothered tone of which the orchestral instrument is entirely innocent. I remember sampling a specimen of the capped clarinet in an organ which had only recently been erected by a builder now deceased: my friend, Mr. John Stuart Archer was with me—than whom there is none more gifted with the faculty of judging tone quality at its real worth—and his comment on this particular reed was that it "was like a strangled duck." True, better specimens than this one are to be found, but I have yet to hear a really satisfactory example. A well-voiced clarinet is not a soft stop: on an open soundboard it is really too powerful, hence possibly the reason for capping. All imitative stops should be enclosed in a swell box, and certainly the clarinet. The scaling of this reed varies both absolutely and relatively with various voicers. It has, however, to be borne in mind that there is a limit in either direction for the absolute scale, since if the tube is made too wide the pipe ceases to give true clarinet tone and becomes a **krummhorn,** and if too narrow it becomes a **musette.**

A really safe scale is:—

CC (8 ft.) 1¾ in.; tenor C (4 ft.) 1¼ in.; middle C (2 ft.) 1⅛ in.; treble C (1 ft.) 1 in.; C in alt (6 in.) ⅞ in.

It should, however, be pointed out that the pipes from middle C up **may** be all the same scale with excellent results; in fact, Mr. R. W. Davidson (of Messrs. Kingsgate, Davidson Co.) has given his clarinet on the choir manual of his fine organ at Brompton Parish Church a uniform scaling from the **tenor C** pipe to top. Other voicers adopt the "sevens and fives" scale ratio: that is, they make the tenor C (4 ft.) tube and the next six tubes above to F sharp the same diameter, then G to B above (five notes) are made to a smaller diameter (though only smaller by 1/16 in.), and so on. The length of the middle C tube is 1 ft. 1½ in. The conical tip should be made to the correct length so that the inside diameter of the tip or narrow end may be a third of that of the wide end (which is that of the tube). If a compensator sleeve is fitted to the top of the tube the tone is somewhat broader and fuller, but also more "woody." For this reason I have treated my own clarinet at Stagsden in this manner, the top of the tube having adjustable cardboard sleeves, and the scale being as above formulated. These pipes were made for me by Mr. C. H. Clarke.

The 16 ft. and 8 ft. octaves are treated on similar lines as the upper octaves except that the relative scaling follows that of a normal reed, namely half on the thirty-second note. The CCC pipe may be 2¼ in. in diameter with a length of 9 ft. 4 in., while the CC pipe may be 1¾ in. and 4 ft. 7 in. long. The tongues of these lower octaves must be weighted and the curve distributed evenly with the minimum of amplitude consistent with a full-toned note. The fundamental harmonic is well pronounced and followed by the odd partials only. If a conical bell is fitted to the top of the tube, even harmonics are introduced. Some voicers contend that since the orchestral instrument has even as well as odd harmonics—they are 1, 12, 17, 19, 21, 22, 23, 24, 25 at middle C note—the addition of bells is justified; but unfortunately the harmonic content is not thereby reproduced. There is no rational objection, of course, to such a stop; but I do not think it should be labelled "orchestral clarinet." I should prefer to call it "bassethorn."

The shallot employed for the clarinet is the same as that of the trumpet, though the type illustrated at D in Plate IV is sometimes adopted. I have tried every form from the open to the closed types and have to confess that there is very little difference in actual results. If, however, the shallot opening is reduced to the short length of that at D, the tone is apt to be dull, while a shallot with an opening as at G favours certain higher harmonics if fitted to pipes below middle C. The reason why the actual type of shallot does not influence the tone to any serious extent is because the even harmonics are absent: the cylindrical tube effectually masks any overtones introduced by the vibrating system other than the odd partials, especially from middle C up.

If we reduce the diameter of middle C tube (for example) to ¾ in., the quality becomes much thinner. In this case the shallot with the low opening at D is indicated with a view to securing a "pastoral" tone, and moreover it is permissible to cap the tube and either slot it or introduce (as Mr. Compton has done) a small hole at a distance of a third of the pipe-length from the top. This is the **musette.**

The **orchestral oboe** (so named to distinguish it from the quasi-chorus oboe described in Chapter V) is a genuine attempt to imitate its orchestral prototype, but fails to do so. In proof of this statement I may say that I have heard an oboist perform on his instrument in close proximity to the pipes of the organ stop of this name—the voicer had designed and treated the pipes with the utmost skill at his command and with the fullest possible intention of attaining the true quality of the original. The difference was ludicrous. The orchestra alone can boast of the possession of Berlioz's "acid-sweet" oboe. The late J. M. Boustead was of the opinion that if the tube of an ordinary organ oboe pipe is cut down below the bell to about a third of its length, making middle C about 8 in. long, the closest possible resemblance to the orchestral instrument is obtained. This is not so: there is no real resemblance. The resulting tone is interesting and there is a thin piquancy which at first hearing may possibly delude one into imagining a resemblance to the original; but the harmonic content has not been captured. In fact, the Haskell "labial oboe" approximates more closely. The reed stop is nevertheless worthy of a separate existence, despite its failure to reproduce the orchestral tone.

There are two main types found in the organs of our English builders. One is the Father Willis type shown in Plate III, with its narrow-scaled conical tube, completely capped at the top and slotted below. The scale at CC (8 ft.) is 2 in. The other is a reduced scale version of the normal oboe pipe, both tube and bell (with half-cap) being much narrower. This is shown in Plate VI and occurs in organs by Messrs. J. W. Walker and Messrs. Harrison and Harrison. Messrs.

Henry Willis and Sons also use this type, but call it "cor anglais." The scale at the 4 ft. pipe is of the order of 2 in. (maximum) at the top of the bell and ¾ in. at the bottom (where the bell and tube are joined). A small hole is sometimes pierced in the bell at a point halfway between top and bottom.

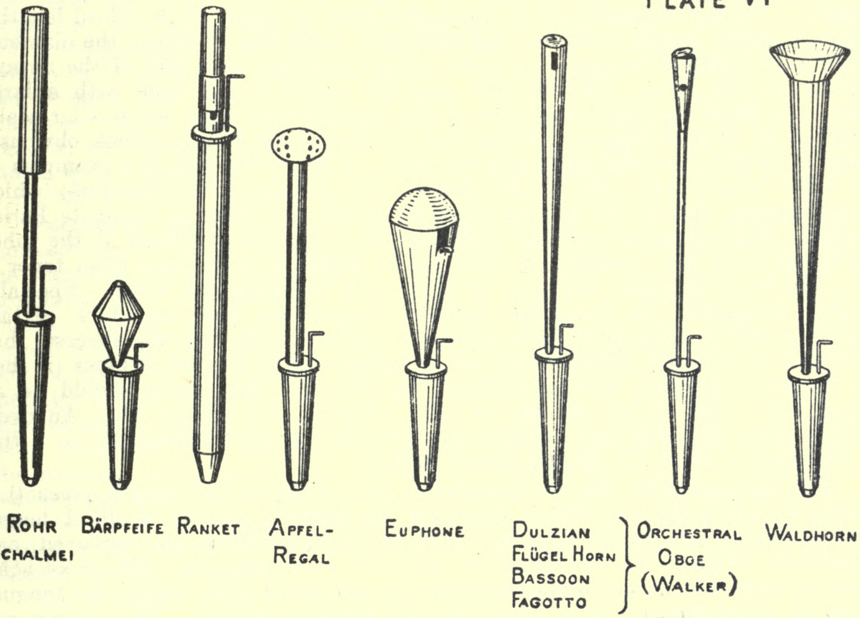
The shallot employed for this type of reed is usually very narrow and is illustrated at F in Plate IV. The back portion of the base is often cut away at an angle with the object of thinning the tone. The tongues are curved similarly to those of the clarinet. Some voicers favour thick tongues and high pressure. There is no doubt that it is easier to obtain a thin, piquant **timbre** by this means. Aluminium tongues might be tried with good results, but they would require a very fine distribution curve.

The bass of all orchestral oboes may be made of pipes of the Willis type.

The **Cor Anglais** or **English Horn,** as shown in Plate III, has a conical tube surmounted by a double bell first widening and then narrowing. This particular form of bell acts as a resonator emphasising the 3,000 cycle frequency, while the complete pipe-body consisting, as it does, of a relatively long conical tube of narrow cross-section plus the specially shaped bell, tends to accentuate the 300 cycle frequency. Thus a formant of 300 and 3,000 frequencies is imposed on the air-column of the tube and the result is a tone in which the vowel E (as in **bee**) is introduced. Actually, only a suspicion of this vowel sound is ever present in the stop as a whole: it would only be noticeable in certain pipes owing to various other factors co-operating in the acoustic system of the pipe and its environment which are not calculable in any method of voicing. The second, third and fifth harmonics are audibly perceptible in the tone of the orchestral instrument, with, of course, a cluster of higher partials plus the formant. It is, therefore, fatal to cap and slot the tube of the organ reed pipe if the true cor anglais quality is to be even remotely reproduced, since this process introduces the wrong harmonics from a small-scaled tube and is more suited to the production of oboe quality. If, however, the top of the tube is surmounted by a dome (such as is illustrated in the drawing of the Euphone in Plate VI), a slot is quite permissible and indeed essential. In fact, a pipe of this formation, consisting of a half-length conical tube (similar to that used for the bassoon) with a dome-topped bell and a slot cut below the dome portion would probably provide the best solution till something better is evolved. The dome would take the place of the upper half of the more conventional double bell shown in Plate III. The tone of the organ cor anglais is difficult to describe: a hollow, horny and rather thin quality with a suspicion of nasality is the best I can attempt by way of a description. The shallot employed is usually that of the normal oboe pipe, though the "orchestral" type can be chosen.

The **Vox Humana** is probably the best known of all organ stops! It is castigated by the purist and adored by the sentimentalist. It is in reality only a reed pipe insufficiently controlled by its resonator—the one reed which allows its vibrating tongue and shallot to take the major part in producing the note. Reference to Plate VI will show four reed pipes—**Bärpfeife, Ranket, Apfel-Regal and Euphone**— which also belong to this particular category in which the tongue is the master-voice. The last pipe of Plate III is the conventional vox humana. It is safe to say that all five varieties of resonator represent differing attempts to shape the **timbre** of the reed note without interfering unduly with the harmonic content of the vibrating system in the boot. Thus, the bärpfeife gives a smothered growl (supposed to imitate the voice of the bear!): the ranket shown in Plate VI is a modern type designed by G. D. Harrison (see Appendix I), the original type giving a wheezing, bottled-up sound: the apfel-regal, with its apple-shaped head, pierced with pepper-castor holes, utters a nasal twang: the euphone gives a hollow, sepulchral note tinged with a flavour of acidity. These are all types of vox humana, found in Continental organs of the sixteenth and seventeenth centuries. They were **not** intended primarily as solo stops but as "tone-formers," mixing with the upper work and adding a distinctive flavouring to the ensemble. Schnitger found the bärpfeife useful in colouring his mixture work, the gentle buzzing tone served as a condiment which no mixture could provide. I have only given a selection of the numerous shapes of resonator applied by the old builders to the "regal" pipe. They are not used by English builders now; but the vox humana of Plate III still claims its devotees. The **rohr schalmei** is described in the Appendix.

PLATE VI



IMITATIVE REED PIPES

Does the vox humana give a fair impression of the human voice? It undoubtedly does under favourable acoustic conditions. Those conditions are (a) a resonant building, (b) a remote position for the pipes, (c) enclosure in a swell box, and (d) skilful treatment. "I hope I don't sing like that," was once the remark of a highly offended tenor vocalist on hearing a solo played on the vox humana with tremulant. Perhaps he did not sing like that : "that" may be interpreted in a multitude of different ways. The well-voiced vox humana can give points to many a modern vocalist who could do with a little revoicing on his own account. The **smooth, unforced** tone of a properly scaled and voiced vox humana stop presents its challenge to the human singer which he would do well to accept. Father Willis, Cavaillé-Coll, J. W. Walker—to mention three men no longer with us—knew how to make and voice this reed. E. H. Lemare knew how to use the Walker stop at St. Margaret's, Westminster: not as a solo voice, but in combination with strings. William Wolstenholme hated it as a single stop, with or without tremulant, but liked to press it into service with the string celestes plus octave coupler.

The tube is cylindrical, so that a clarinet pipe can be converted into a vox humana by cutting the tube in half to make a "quarter length," or further down still to make an "eighth length." Or again, the tube may be cut to a "third length." Thus, the tenor C (4 ft. tone) pipe may be either 17 in. (third length), 13½ in. (quarter length) or 8½ in. (eighth length), according to choice, the diameter of the tube being of the order of 1½ in. (which is larger than that of the normal clarinet at this note). Cavaillé-Coll used the eighth length tube with a large scale, and there are many examples of the eighth length type (of smaller scale, however) in English organs. Willis prefers the quarter length, which obviously keeps in better tune and gives a purer note. I have designed two examples of the third length type, one at All Saints', St. John's Wood (London), which Wolstenholme used in the manner above described, the other at Sandgate Parish Church. The quality of each type differs in the harmonics developed by the tube; but in all cases it is desirable to encourage a **flutiness** in the tone from tenor C up. The tubes are best left open or fitted with half-caps and slides. Specially shaped headpieces to encourage formant frequencies and reproduce certain specific vowel sounds have been tried by builders with varying success; but surely, since only **one** vowel sound can be reproduced in one set of pipes (if they are to give a uniform tone throughout the compass) that vowel should be an "open one" such as 'ah' or 'aw' or 'oh': certainly not 'ee' or 'ai.' An overlapping dome top will help considerably towards the reproduction of 'ah': this is indicated in Plate III by the dotted outline.

The top octave of the vox humana is best made of half length pipes (i.e. clarinets), while the CC octave preserves the eighth, quarter or third length tube chosen for the middle section. Oboe or clarinet shallots are employed, and aluminium tongues are advocated or else soft brass tongues. The boot-holes must be quite diminutive and either short or else bored with holes: the tongues must be given the minimum curve for the pressure applied. The double vox humana or baritone can be found in a few organs, but it is a luxury that can well be dispensed with since the effect desired can be obtained for all practical purposes from the unison rank plus the suboctave coupler. The 16 ft. octave is not wanted, since it makes a very indifferent pedal stop.

A small-scaled trumpet pipe can be utilised for the production of special horn-like reed tones of beautiful quality. To such a category belong the **Dulzian**, the **Flugel Horn**, the **Bassoon** and the **Fagotto**. The diameter of the tube at the top for the 4 ft. pipe would be of the order of 2 in. to 2⅜ in., and the complete cap would be soldered round the top with the usual slot below it. (See Plate VI.) With wind pressures not less than 7 in. really fine results can be achieved, and the blending quality of these pipes is phenomenal, apart from the beautiful solo effects they produce. I have included this type in this list of imitative reed tones because of their undoubted success as solo stops forming part of the "orchestral division" of the Organ, but in reality they belong also to the chorus class in view of their fine blending capacity. The bassoon is, in fact, mentioned in the chapter dealing with chorus reeds. The tuba could with equal reason be included here if I had not already devoted some space to it in the above chapter.

Attempts to imitate the French horn have been made by many organ builders. At first a reed pipe with a wide flaring bell was tried by Messrs. Abbott and Smith, and by Mr. John Compton as shown in Plate VI (the last pipe on the right). Later Mr. Ernest Skinner introduced a large-scaled conical tube with no bell; the chief feature being the double-sized shallot, namely the shallot normally used for the octave below. This shallot, however, has the normal opening placed in the normal position. The tubes are not made harmonic (i.e. they are of normal length) and the fewest possible tongues are weighted. The most suitable pressure of wind is 10 in., though other pressures can be employed. The tubes may be capped and slotted, as desired. Mr. Henry Willis has produced several examples of the French horn in his larger instruments, notably at Westminster Cathedral and St. Paul's Cathedral. Messrs. Rushworth and Dreaper, and also the John Compton Organ Company produce their own examples. In all cases the characteristic feature is the type of shallot employed and the ultra-smooth tone-quality obtained from reed pipes with a tendency to double speech due to the closeness of tuning. The diplophonic effect is intentional, in imitation of the "bubble" produced by the horn player's lips.

Percussion effects are often introduced into the Organ and greatly add to the resources of the performer; moreover, they make an effective contrast against the sustained tones of organ pipes. They are, of course, an essential part of the equipment of a cinema organ which has to provide imitations of all sorts of sounds, musical, semi-musical and unmusical, when required. Here I am concerned only with the musical variety produced by the striking of metal or wooden bars or solids or of stretched skins by electro-pneumatic hammers. For the operation of the hammers (with heavy metal heads) the auxiliary machine and large motor illustrated in Fig. 46 is quite an efficient mechanism, the motor 2 being controlled by a spiral spring instead of the balance weight there shown. The hammer would be attached to the top board of the motor 2 by means of a flexible steel shaft, and after the impact the head must spring back immediately so as to allow the object struck to vibrate freely. The hammer head may be padded with leather or felt according to the type of tone required, whether brilliant or dull or muffled.

The principal kinds of percussion are as follows:—

Celesta, gongs, carillon, glockenspiel, chrysoglott, vibraphone; marimba, xylophone; drums (tap and roll), cymbals, triangle, and piano. The first six are produced from metal bars, the next two from wooden bars, and the last four from the actual instruments known by these names and adapted in size and construction, if convenient, to the needs of the organ builder. The celesta consists of short, oblong metal bars screwed to a frame and diminishing in size for each ascending note of the musical scale. It is sometimes called "organ harp." The gongs are resonant metal cavity bars; the carillon consists of hollow tubular rods of metal; the vibraphone has celesta bars preferably made of aluminium, which after being struck continue to vibrate for an appreciable period and thus produce an undulating effect of great charm. This sustained undulation is effected by means of rotating discs or vanes (operated by a small electric motor) which are placed in the mouths of cylindrical resonating tubes and cause the internal air column in each tube to oscillate; the oscillation affects the air around the vibrating bar and sets up sympathetic vibrations. If the bars are made of aluminium it is necessary to introduce dampers.

CHAPTER IX

Tonal Architecture

HOW should the various stops of the Organ be distributed? This is to be our next theme for discussion. In other words, what is the best kind of specification or stop-list for an organ of a given number of speaking stops or ranks of pipes?

Tradition has handed down to us certain well recognised tonal departments or divisions called "organs," such as the great organ, swell organ, choir organ, echo organ, solo organ, orchestral organ, bombarde organ, pedal organ. At one time the only "organ" that was enclosed in a swell box was the swell organ: now all the "organs" may be enclosed either in the same box or in separate boxes or else distributed in two, three or more boxes. Or again, certain selected stops or stop-groups of an "organ" may be enclosed in a swell box while the others are kept outside; or every "organ" except the great (representing the diapason chorus) may be enclosed in one or more boxes. It is the opinion of one school of designers that the diapason chorus (on the great manual) should always be unenclosed, while all solo or orchestral stops should be enclosed, and all the reeds with the possible exception of those on the great manual and the solo tuba. Some would have the choir organ enclosed, others say "No." **There is no general agreement on this question of enclosure.**

On what manual keyboards should the various tonal departments be playable? Tradition allocates the diapason chorus to the great manual (the middle keyboard of a three-manual organ in this country); and the "expressive reed chorus" to the swell manual (or top keyboard of a three-manual organ); the other tone-groups may be made available on any manual including the third or lowest keyboard or the fourth manual which is placed above the swell. Or there may be as many as five or six manual keyboards (the Atlantic City Auditorium has seven) named—from lowest to highest—choir, great, swell, solo, echo, bombarde. One of the manuals may be a "collective" division in which certain selected stops are borrowed from other divisions in order that they may be available to the player in any combination he desires. There is also, of course, the pedal department, which in the modern organ has assumed a very important position, though in Continental instruments it has held this position for many centuries.

German organs of the "baroque period" would possess two or three complete manual choruses consisting of flue and reed work, capped by many ranks of mixtures: a typical example by Silbermann was that in St. Peter's Church at Freiberg (1733), which had the following specification:—

HAUPTWERK.	OBERWERK.	PEDAL.
Principal, 16 ft.	Quintaten, 16 ft.	Gross untersatz, 32 ft.
Octav principal, 8 ft.	Principal, 8 ft.	Principal bass, 16 ft.
Viola di gamba, 8 ft.	Quintaten, 8 ft.	Octav bass, 8 ft.

HAUPTWERK.	OBERWERK.	PEDAL.
Rohrflöte, 8 ft.	Gedackt, 8 ft.	Posauen bass, 16 ft.
Octava, 4 ft.	Flöte, 4 ft.	Trompeten bass, 8 ft.
Spitzflöte, 4 ft.	Octava, 4 ft.	
Quinta, 2⅔ ft.	Nasat, 2⅔ ft.	
Superoctava, 2 ft.	Octava, 2 ft.	
Tertia, 1-3/5 ft.	Quinta, 1⅓ ft.	
Mixtur, IV ranks.	Sifflet, 1 ft.	
Cymbel, III ranks.	Sesquialtera, II ranks.	
Cornett, V ranks.	Mixtur, III ranks.	
Fagotti, 16 ft.	Vox humana, 8 ft.	
Trompete, 8 ft.		

The "hauptwerk" (head or main work) corresponds to our "great organ" and contains a broad and dignified chorus, while the "oberwerk" (upper work) contains a sharper-toned chorus. The pedal has no mixture ranks in this case, but in the majority of pedal organs at least one mixture was considered essential as a connecting link between pedal and manual choruses. A third chorus of delicate voicing would be called the "brustwerk" (breast work) corresponding to our enclosed choir division.

Another interesting example of a modern "baroque" specification comprising only fifteen speaking stops is that of the chamber organ at Cleveland House, Dorking, Surrey, the home of Lady Jeans. It was built by Hermann Eule of Bautzen. It is especially designed for the playing of Bach, an accomplishment in which, among others, Lady Jeans excels.

HAUPTWERK.	OBERWERK.	PEDAL.
Gedackt, 8 ft.	Quintadena, 8 ft.	Subbass, 16 ft.
Principal, 4 ft.	Rohrflöte, 4 ft.	Holzflöte, 8 ft.
Spillpfeife, 4 ft.	Principal, 2 ft.	Gemshorn, 4 ft.
Quint, 2⅔ ft.	Quint, 1⅓ ft.	Nachthorn, 2 ft.
Octave, 2 ft.	Octave, 1 ft.	
Mixture, 19, 22, 26.		

The absence of any unison diapason will be noticed: the diapason chorus of the "hauptwerk" is based on the principal, 4 ft. instead of the usual open diapason, 8 ft.—a feature of the "baroque" tone-scheme. I have in a previous chapter referred to the cohesive effect of chords played on stopped 8 ft., principal, 4 ft., twelfth, fifteenth, without the unison open diapason. There is, of course, a lack of "body" in the tone-picture which those accustomed to the English flue chorus based on a powerful unison diapason would miss. But then it is this very feature of slenderness that the "baroque devotee" so much admires: the tonal shape of the chorus is considered far more in keeping with the music of the polyphonic school of which Buxtehude, Pachelbel, Bach and Handel were the exponents in this period. Cohesion of the various tone-units making the chorus, and clarity of the part-work, are the two essential desiderata for the proper interpretation of these classics: each part (or voice) must be distinct in the rendering of the score, and at the same time the total effect must be harmonious and significant. Fat-toned unisonal stops spell certain disaster, as if heavy daubs of black paint were to be splashed upon the delicate lines of a picture. A bright-toned octave diapason rank secures the desired foundation on which the tonal edifice may rest. This, in brief, is the architectural conception of the baroque school.

A somewhat larger scheme for a "Bach organ," built for the Worcester Art Museum (Mass., U.S.A.) by the Aeolian-Skinner Organ Company, possesses the following interesting stop-list:—

GREAT ORGAN (lowest manual).

Quintaton, 16 ft.
Bourdon, 8 ft.
Principal, 4 ft.
Rohrflöte, 4 ft.
Fourniture (II to V ranks).

RECIT (top manual).

Rohrflöte, 8 ft.
Prestant, 4 ft.
Cymbel (IV ranks).
Cromorne, 8 ft.

POSITIF (middle manual).

Quintade, 8 ft. (unison).
Koppelflöte, 4 ft. (8ve).
Nazard, 2⅔ ft. (12th).
Doublette, 2 ft. (15th).
Tierce, 1-3/5 ft. (17th).
Larigot, 1⅓ ft. (19th).

PEDAL.

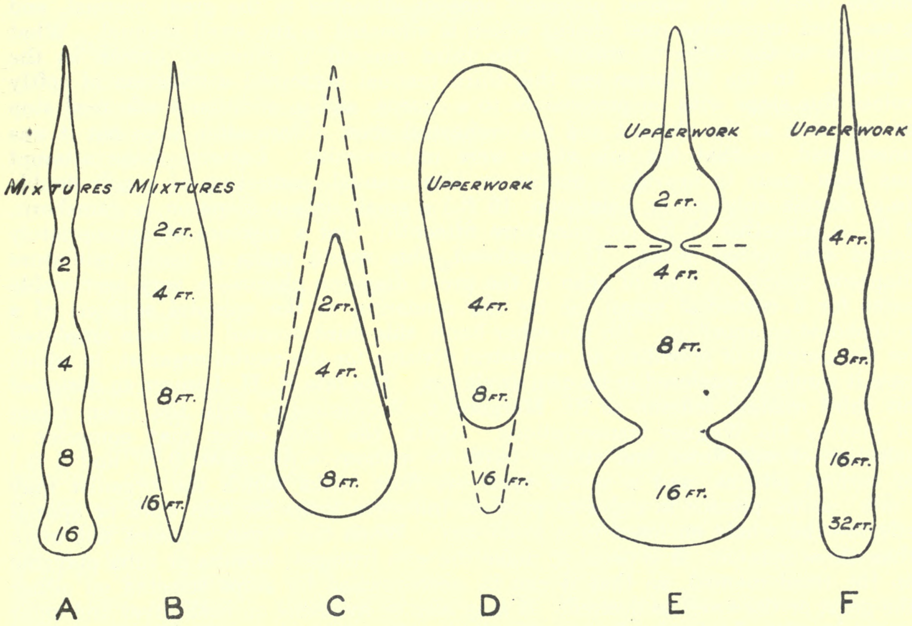
Rohr Bourdon, 16 ft.
Quintaton, 16 ft. (from Great).
Principal, 8 ft.
Quintaton, 8 ft. (from Great).
Nachthorn, 4 ft.
Blockflöte, 2 ft.
Fourniture (IV ranks).
Posaune, 16 ft.
Trompette, 8 ft.
Rohr Schalmei, 4 ft.

Wind pressure, 2½ in. throughout: no swell boxes—every stop in the open.

It will be seen that without mixture work these "baroque" schemes would be lost. The tonal picture is set in a framework of transparent material based on the octave diapason which is in reality the standard pitch. The main theme of a Bach fugue and its initial development would be played on the great, and the episode taken on the recit; while the tenor part could be played by the left hand on the positif or the recit, both of these manuals being interchangeable by means of transfer tablet mechanism. The pedal passages would stand out with a clarity of emphasis only possible with a complete chorus of independent stops. Bach, as is well known, wrote many of his fugues for the harpsichord, and the tone of this instrument is full of high-pitched harmonics with only a modicum of fundamental. The baroque tone-medium in terms of organ pipes does seem on the face of it to present a similar characteristic, while the "chromotonic mean" of the chorus effect of each division can be centralised by careful regulation of each contributory rank of pipes in due relation to the whole.

The subject of the chromotonic mean must here be discussed in further detail. Figs. B, C, D of Plate VII give three chromotonic shapes presenting at C a bottom hump, at D a top hump, and at B a slender middle hump. The chromotonic mean occurs at the bottom at C, at the top at D, and at the middle at B. Obviously, B is the ideal presentation: it is certainly the best of the three. The listener's mind is directed to the central zone of aural impressions, yet not unduly. If the unisonal foundation is excessively developed we get the figure at C, and no amount of 4 ft. or 2 ft. work will alter the bottom hump. Even the addition of brilliant mixture-work, as indicated by the dotted extension lines, cannot liquidate the hump. If, on the other hand, the unisonal foundation is considerably reduced and the octave and mutation work built up to an extremity of brilliance, we get the top hump of Fig. D, and even the addition of a 16 ft. double (as indicated by the dotted lines) cannot effect the balance. At B the unison and octave are correctly proportioned in relation to the double and the upper work. If the double is omitted, the whole of the figure is put out of shape and the unison and octave must be modified in order to restore the proportions. It means, in practice, the reducing of the fundamental strength of the unison and the increasing of the **harmonic** strength of the octave. The relationship between unison and octave will then be substantially that of stopped 8 ft. to a principal or geigen, 4 ft.

PLATE VII



VARIOUS TYPES OF TONAL STRUCTURE

It must be understood, however, that the various pitch-tones cannot be linked together as shown at B, C, and D (which represent ideal figures) but exhibit "waists" as shown in the other figures of Plate VII. The object of the tonal architect is to eliminate these waists as far as possible, though in fact he can only succeed in reducing them to a minimum. Fig. A gives the tone-shape to be aimed at, free from humps and with a minimum of waists, while Fig. F gives the tone-shape achieved by Schulze at Doncaster. Fig. E is the Hope-Jones formation, with its massive unison and heavy double effect. Above the horizontal dotted line is shown the effect of adding upper-work to this foundation—a grotesque figure indeed, with a wasp-waist at the point of connection. Many, many organs in this country afford examples of this formation in a modified degree: at their very best they can only approximate to the ultimate shape shown at C.

Reverting to the more conventional type of organ scheme, we find a diapason chorus which is by almost universal consent allocated to the great manual, and a so-called expressive reed chorus which is allocated to the swell manual. What happens to the other manuals? The third manual is generally known as the "choir." In the Victorian era this third manual contained a selection of softly voiced flue stops with no pretensions to a chorus, and in addition a solo reed stop or two such as the clarinet and the orchestral oboe. More often than not it was unenclosed, so that the solo stops were unexpressive. Latterly some attempt has been made to provide a chorus on this manual, consisting of a soft double (e.g. double dulciana or quintaton, 16 ft.) a small unison diapason, a gemshorn, 4 ft., a salicetina, 2 ft. (or miniature fifteenth), and a mixture of appropriately scaled and voiced ranks. If unenclosed, this would make a useful miniature diapason chorus, a kind of echo of the great diapason chorus—a very serviceable asset for a cathedral organ, or for the rendering of the episodal sections of a polyphonic composition. On the other hand, this third manual has been employed for the purpose of providing an orchestral division for the recital organist, in which case it would be enclosed in its own swell box. The late E. H. Lemare so designed his third manual scheme at St. Margaret's, Westminster, with the main object of playing his Wagner transcriptions. Again, the choir organ may comprise a selection of soft flutes and strings (with or without a diapason, 8 ft. and 4 ft.) of various pitches, and a set of synthetic flute ranks which the organist may "mix" as he pleases in order to produce imitative tones for solo work or special effects—the whole enclosed in a swell box. When the organ contains not more than three manuals, it is usual to make the solo trumpet, tromba or tuba playable on the third manual, so that it can be accompanied by stops selected on either the great or the swell as desired. It may also be available on both great and choir manuals with duplicate drawstop control. In some organs the choir manual contains a selection of unenclosed stops as well as enclosed stops, so that the player may have either a "cathedral choir section" or an expressive echo or orchestral section at his disposal.

The fourth manual is usually reserved for solo stops with or without a family of powerful trumpets or tubas, and these stops are almost invariably enclosed in a swell box, with the possible exception of the tuba or tuba family. If there is a fifth manual above this, it is employed for various echo stops, which may or may not be enclosed. At Armley the fifth manual controls the echo division which is unenclosed and voiced on 1½ in. pressure, while at Doncaster the echo organ on the fifth manual is enclosed and on 1⅝ in. pressure.

The following example of a three-manual tonal scheme will, I hope, suffice to illustrate the points enumerated above:—

GREAT ORGAN.

Bourdon, 16 ft.
Open Diapason, 8 ft. (1).
Open Diapason, 8 ft. (2).
Waldflöte, 8 ft.
Dolce, 8 ft.
Principal, 4 ft.
Gemshorn, 4 ft.
Twelfth, 2⅔ ft.
Fifteenth, 2 ft.
Full Mixture, 19, 22, 26, 29.
Tromba, 8 ft.

SWELL ORGAN (enclosed).

Geigen, 8 ft.
Rohrflöte, 8 ft.
Aeoline, 8 ft.
Celestes, 8 ft. (T.C.).
Geigen Principal, 4 ft.
Spitzflöte, 4 ft.
Cornet, 12, 15, 17, 19, 22.
Double Trumpet, 16 ft.
Trumpet, 8 ft.
Oboe, 8 ft. (echo trumpet).
Clarion, 4 ft.

"CHOIR" ORGAN.

Scheme No. 1 (enclosed).

Double Dulciana, 16 ft.
Early English Diapason, 8 ft.
Stopped Diapason, 8 ft. (old type)
Dulciana, 8 ft.
Early English Principal, 4 ft.
Nason, 4 ft. (stopped diapason).
Spitzflöte, 2 ft.
Dulciana Mixture, 8, 12, 15, 17.
Tromba, 8 ft. (from Great).
Clarinet, 8 ft.

Scheme No. 2 (unenclosed).

Quintaton, 16 ft.
Gedackt, 8 ft. (metal).
Principal, 4 ft.
Koppelflöte, 4 ft.
Nazard, 2⅔ ft.
Gemshorn, 2 ft.
Sesquialtera, 17, 19, 22.
Cymbal, 26, 29, 33.
Rohr Schalmei, 16 ft.
Bärpfeife, 8.
Tromba (from Great).

A few comments on the above specification will serve to elucidate the basic **motif** underlying each tonal department.

1. **Great Organ.** The true diapason chorus consists of No. 2 unison diapason, principal, twelfth, fifteenth and mixture, which are scaled and voiced to produce a homogeneous diapason ensemble in accordance with pattern A of Plate VII. The stopped double (bourdon) is not essential to this chorus (at any rate from the voicer's point of view), but may be added by the player as and when desired. A 16 ft. open diapason could, of course, be substituted for the bourdon; but it would need extremely careful treatment. The double of this manual, whether open or stopped, would by most organ designers be duplicated on the pedal organ (but of this later). The No. 1 diapason **could** be fitted into the chorus, if so desired, but is not essential to it. Its purpose is to add foundation to the organ as a whole when it is felt that greater massiveness of unisonal tone is required: as, for instance, in the accompaniment of the church service in support of congregational singing or on festival occasions. The waldflöte is **not** intended to bolster up the diapason foundation but to provide a **change of tone** for accompanimental purposes with sufficient prominence to be independent of any support from other stops. The dolce is generally regarded by organists as the most serviceable soft stop for accompanying solo stops (e.g. clarinet or oboe) on the other manuals, especially when it is desired to change quickly from the solo stop of the choir to another solo stop on the swell. Although the dolce (or its equivalent) is not enclosed in a swell box (though it **could** be). in the above scheme, it can be voiced

to give a neutral tone capable of providing the necessary accompaniment to enclosed solo stops, as has been proved over and over again. The gemshorn, 4 ft. is a miniature principal and is designed to blend with either the smaller diapason or the waldflöte. Lastly, the tromba, on its own separate chest and wind-pressure, is available for solo effects on either the great or the choir manual, and can also be added to the full great chorus for producing a climax.

2. **Swell Organ.** The expressive reed chorus consists of double trumpet, trumpet, clarion (with or **without** the octave geigen), plus the five-rank cornet. The reeds are scaled and voiced to give "free" and fiery tone, the actual degree and intensity of harmonic development being determined by the acoustics of the building. The double trumpet, trumpet and clarion can, if desired, be planted on a separate soundboard and duplicated on the pedal organ: they would then be available for expressive reed pedal passages in the playing of choral preludes and of Bach and other polyphonic composers. The oboe provides a miniature chorus reed tone (but must be so constructed and voiced as to produce this quality instead of the much more usual smooth, horn tone), though such a tone is not of much use unless octave couplers are available: it will then be possible to extend the oboe in double and octave pitches and add the cornet so as to provide an "echo full swell." If the double trumpet is duplicated on the pedal it will supply the 16 ft. reed bass for this miniature chorus. The geigens, 8 ft. and 4 ft. are necessary in order to provide an expressive diapason effect in contrast to the unexpressive great diapasons, and the cornet can be added for the full flue chorus effect. The spitzflöte is much softer than the geigen principal and can be combined with the rohrflöte or even with the aeoline: it may also provide a quieter octave to the geigen, 8 ft. The rohrflöte (of metal) is useful in combination with the aeoline or the geigen or as a soft accompanimental flute: or it may be used as a soft solo stop. The aeoline is a string-toned stop of ethereal quality as described in Chapter III, and the celeste rank is of similar construction tuned to beat with the aeoline. A couple of sylvestrinas or salicionals or muted viols could be substituted, or indeed any type of echo string tone.

3. **The Choir Organ.** Two alternative schemes are given for the third manual, because there is a considerable divergence of opinion among tonal architects on the whole subject of choir organ design. Scheme No. 1 is intended to reproduce the early English diapason chorus as far as is consistent with the need of providing a reasonably flexible division to meet the requirements of the modern organist. Thus, it is enclosed in its own swell box: it contains a 16 ft. and 8 ft. dulciana plus a dulciana mixture to complete the family; and a solo clarinet is included as well as the duplicated tromba. Scheme No. 2 is frankly "baroque" and therefore not enclosed. The flue-work speaks for itself, but the reeds are a special addition designed to produce a special effect. The bärpfeife (described in Chapter VIII) with its "smothered growl" lends a peculiar flavouring to the cymbal when these two in combination are superposed on the quintaton, gedackt, principal and gemshorn (with or without the nazard and koppelflöte). The rohr schalmei must be voiced as a **soft** double reed of clarinet tone (see Appendix), not to go with the bärpfeife, but to blend with the flue chorus with or without the addition of the bärpfeife. The great tromba is duplicated here as in scheme No. 1: it does not in either scheme form an integral part of the third manual division, but the third manual **keyboard** is utilised for making the tromba available on more than one keyboard, so that it may be accompanied by either the great or the swell (suitable stops for this accompaniment being selected from either division).

It would be easily possible, funds and space permitting, to build a four-manual organ in which both the above choir schemes could be incorporated: or alternatively, both schemes could be included in the third manual specification: or again, the enclosed No. 1 scheme could be made a "floating division," which means that this particular section of stops would be made available on all three manuals by means of a duplicating mechanism with a transfer control enabling the organist to switch this section on to great, swell or choir as desired. Supposing this section to be labelled "Accompanimental" (instead of "Choir"): then three separate control tablets could be provided labelled respectively, "Accompanimental on Great," "Accompanimental on Swell," "Accompanimental on Choir." This would give the player a most useful selection of accompanimental tones readily available wherever required. The clarinet might be included in this section, since it would be an unnecessary expense to provide a separate chest for it. Unit chests could, of course, be chosen for these stops, but I am not in favour of such chests for the reproduction of early English tone, though this is a matter of opinion. (See the chapter on chests and soundboards for a discussion of the merits of various types.)

As regards the wind pressures suitable for the various departments above scheduled, I suggest a maximum pressure of 3½ in. for the great flue-work, a maximum of 4½ in. for the swell flue-work, 2⅜ in. for the early English choir as well as for the baroque choir. The swell trumpets may be on any pressure up to 5 in. for a building of moderate size (given reasonable acoustical conditions), and not more than 7 in. for any building. Higher pressures may be needed for abnormal conditions, but it must be borne in mind that chorus reeds of the trumpet class on 8 in. or more exhibit a definite change of characteristic. I know of several examples of Father Willis swell reeds originally voiced on 7 in. which have been revoiced on a higher pressure. These are no longer Willis reeds, nor do they blend with the great diapason chorus (when added by means of the swell to great coupler). The remaining reeds, choir clarinet, baroque rohr schalmei and bärpfeife, may be voiced on the fluework pressure: also the swell oboe.

Our next consideration is the pedal department. For the above three-manual scheme the following list of stops would seem adequate:—

PEDAL ORGAN (Compass of 32 notes, CCC to G).

Open wood, 16 ft.
Geigen Bass, 16 ft.
Bourdon, 16 ft. (from Great).
Dulciana Bass, 16 ft. (or Quintaton, 16 ft.) from Choir.
Octave wood, 8 ft. (extension of Open wood).
Gedackt, 8 ft. (from Bourdon).
Flute, 4 ft. (from Bourdon).
Double Trumpet, 16 ft. }
Trumpet, 8 ft. } from Swell.
Clarion, 4 ft. }
Trombone, 16 ft. (extension down from Tromba)
Tromba, 8 ft. (duplexed from Great).
Harmonics, 12, 15, 17, 19, ♭21, 22.

The open wood, geigen bass and mixture would be "independent." The great organ bourdon would have to be planted on a separate chest from CC to G above middle C; likewise the Choir double dulciana (or the baroque quintaton, if this is utilised on the pedal). The swell trumpets are, as already mentioned, on their own chest for this purpose as well as for the purpose of giving them a higher wind pressure than that supplied to the fluework and oboe. The gedackt, 8 ft. can be duplexed entirely from the bourdon if the latter is planted on a separate chest from CC to G above **treble** C (or the whole of the 61 pipes are so planted): otherwise both the gedackt and the flute must have their topmost octaves of pipes added separately on their own chests. Since this means the addition of twelve pipes only in each case, it is not a difficult matter. The trombone would stand on a twelve-note chest, the remaining upper portion being derived from the manual tromba. But it is really better to give the trombone **two** octaves at least of independent pipes (if not the complete thirty-two pipes), if suboctave and octave couplers are introduced on the third manual for use with the tromba; since it will be desirable to make the pedal reed somewhat weightier and fuller in character than would be suitable for the lowest thirty-two notes of the manual reed. The manual tromba is also duplicated on the pedal at the same pitch, and thus the necessity of giving a different scaling and treatment to the pedal 16 ft. reed becomes obvious.

Some designers would miss the "resultant 32 ft." This effect can be supplied by the addition of a stopped quint, 10⅔ ft., which would also form part of the six-rank mixture when drawn with it. There are those who advocate an entirely independent pedal organ, allowing no derivations or duplications at all. But imagine the cost entailed and the space required! The pedal pipes are the most expensive of the organ, and the result would not be commensurate with the cost. Moreover, if 16 ft. stops are included in the manual scheme there is no reason why they should not be made available on the pedal. When played on the pedal these stops need not be drawn on the manual at the same time. The two independent 16 ft. flue stops on the pedal—open wood and geigen bass—provide adequate bass for manual combinations in which the manual doubles are included, while the borrowed bourdon pipes on the pedal would not be relied on alone to give pedal support to the great diapason chorus. Some designers would insist on a second bourdon (preferably independent) on the pedal, but is it really necessary? An independent bourdon would be indicated if the great organ double were a diapason instead of a stopped flute, in which case the pedal geigen bass would be borrowed from this diapason double. It would be possible to borrow the pedal quint from the bourdon as well as the gedackt and flute, but an independent quint is advisable since a satisfactory resultant effect cannot be guaranteed unless the voicer is free to adapt the strength and tone of the quint to the acoustical conditions of the building and site. A real 32 ft. pedal stop would undoubtedly be a grand addition if it could be afforded and if height and space were available. (See Chapter VI for a description of the various types of 32 ft. stop.)

There are three main objectives which the tonal architect should always have before his mind—indeed these three objectives sum up the aim of all artists in whatever sphere they work, whether painting, sculpture, poetry, drama, musical composition, or any of the fine arts. They are (1) beauty, (2) pattern, and (3) surprise. The last-named is very important though not so readily recognised as an objective. We know that a work of art is a failure if **any** of the three requisite features are absent or if their opposites are apparent in the concrete presentation of the picture. Ugliness, shapelessness, mediocrity—these are damning features. It may be true—as a certain school of philosophy known as subjectivism holds—that beauty is a matter of individual taste; yet there exist certain almost universally accepted canons which define where or in what respects a work of art fails in its first objective. It may be a matter of individual opinion whether this or that is beautiful, but **collective** opinion is far more fastidious a critic if it represents the opinion of a cultured maturity. The difficulty, however, of getting a number of people to agree on questions of individual taste is so well known that it is necessary to take into account the other aims of the true artist side by side with that of beauty. The trefoil of beauty, pattern and surprise must not be stripped of any of its leaves. If tastes differ as to the beauty of a thing, can they differ as to the **fact** of shapeliness? I hardly think not. Pattern of some kind there must be, and the pattern must be well-defined. A candidate submitting for his "exercise" for the degree of Bachelor of Music at a recognised university a musical composition devoid of form could not expect to have it accepted by the examiner: it must at least be an art-form. So, too, I submit, must be the tonal scheme of an organ. There must be shapeliness, proportion, both in the selection of the ingredients and in the mixing of the colours. Even if a critic or two are unkind enough to accuse it of ugliness, the pattern would at least be there to confound their criticisms. But this is not enough. We need the third element—surprise. The listener must not be able to say, if he is the honest man we give him the credit of being, that he is "not interested." We must attract his attention. He must feel either that he has not heard quite this effect or result before, or that he is irresistibly reminded of something good he has heard before which he imagined he would never hear again. The tone-picture must either be new or a reproduction of what was considered to be inimitable. It is when all three elements of beauty, pattern and surprise are welded together into a trinity of artistic consummation that criticism gives way to admiration. I will give three examples of the successful achievement of this triple objective in the annals of organ building:—Silbermann in Germany with his magnificent blaze of tone composed of lightly blown and artistically moulded diapason pipes; Father Willis with his magnificent blaze of reed tone resulting from a scientific and artistic treatment of every pipe; Edmund Schulze with his magnificent diapason chorus composed of boldly treated pipes standing on palatially designed soundboards. These three men, selected from the past, produced a very definite art-form, their tone-pictures possessed a unique pattern—let critics say what they will—and their organs evoked feelings of astonishment in those who heard them.

To-day, after two world wars, the situation in which the organ building industry finds itself is peculiarly difficult. There is a desire for new forms and expressions, for greater economy and a broader outlook. But the clash of opinion is by no means mitigated. What are we to aim at now? Old forms dressed up in new guise, or new forms dressed up in old garments, or strange new forms in fresh clothing? Are we to make Schnitger our model? Or the Silbermanns? Or Cavaillé-Coll? Or Father Willis? Or Schulze? (I do not hear from any quarter the name of Hope-Jones in this connection, though his influence is by no means dead, and there are many good things which we must place to his credit in the **construction** of the Organ). Or are we to combine the best features of Father Willis and Schulze? Or the best features of two, three or even four great builders? In answer to these questions I would unhesitatingly say: let an organ builder create the best he can out of his artistic sub-consciousness, **after assimilating as much as possible the experience acquired from hearing and testing the works of other great artists.** Slavish imitation is not art, nor on the other hand is an undisciplined straining after original effects. Slavish imitation may produce beauty, but not surprise: uncontrolled efforts at originality may occasion surprise but not beauty. Extremes should be avoided as much as the commonplace.

What, then, is the organ of the twenty-first century to be? No one knows. Yet surely it is not true to say that the Organ, the King of Instruments, has reached the zenith of its evolution. I have already expressed the opinion that in the realm of mixture design and treatment we have still very far to go before finality is attained. I will now add that the diapason chorus and the reed chorus also are still in the throes of evolutionary development: even they have not reached the Aristotelian *telos*. Furthermore, we have yet to discover how to weld into a homogeneous pattern of beauty, diapasons, reeds and upper work. And besides all this, we have to come to some measure of agreement as to the merits or demerits of enclosure in swell boxes. Then again, the principle of multiple service and the increased availability of tonal units on the different keyboards is considered by a certain school of tonal design the only acceptable solution of the economic problem now facing the organ builder. Can the unit or extension system of tonal design be compatible with the architectural ideals of the great masters of the seventeenth, eighteenth and nineteenth centuries? Let us see what this particular system is.

Supposing we select seven stops of pipes, as follows:—

1. Open Diapason No. 1 .... 97 pipes from 16 ft. up to 2 ft. complete;
2. Open Diapason No. 2 .... 97 pipes from 16 ft. up to 2 ft. complete;
3. Stopped Flute .... 97 pipes from 16 ft. up to 2 ft. complete;
4. Geigen .... 85 pipes from 8 ft. up to 2 ft. complete;
5. Dulciana .... 97 pipes from 16 ft. up to 2 ft. complete;
6. Tromba .... 85 pipes from 16 ft. up to 4 ft. complete;
7. Trumpet .... 85 pipes from 16 ft. up to 4 ft. complete.

These seven complete stops or units are placed each on their own chest, and any portion of each unit or the whole of it can be made playable on any manual as well as on the pedal by means of a system of duplexing in unison, suboctave, octave, superoctave or mutational pitch, as desired by the tonal architect. A simple illustration of the system is afforded by imagining a diapason planted on a 97-note chest which is fitted with suboctave, octave and unison-off couplers. If we draw the unison-off coupler, every pipe is silenced: if we draw the unison-off and suboctave couplers together, we get the double diapason, 16 ft. working and no unison or octave. If we draw instead of the suboctave coupler the octave coupler with the unison-off coupler, we bring into play the octave diapason or principal 4 ft. only. Supposing there were twelve more pipes added to the top of the compass of these pipes making 97 pipes in all, then by drawing the unison-off coupler and the superoctave coupler we should get the superoctave diapason or fifteenth, 2 ft. Again, we might incorporate a "quint coupler" or a "twelfth coupler" and by means of these couplers with the unison-off we could get a quint, $5\frac{1}{3}$ ft. and/or a twelfth, $2\frac{2}{3}$ ft. All these couplers could be made to operate not only on the same manual but on any other manual or on the pedal. In the modern electric unit organ the pipes are placed on unit chests with a magnet and pallet per pipe: there is a separate electric contact per key for every speaking stop on the manual: if that particular manual has ten stops derived from the common pool of unit ranks there must be ten contacts per key. From these separate contacts cables are formed and taken to what are called "multiple contact frames"—there would be as many frames as stops—and from these frames more cables are taken to the chest magnets. Thus the action of each stop derived from the unit chest is an electric coupler. Fig. 8 shows a wiring diagram of a 97-note diapason unit at 16 ft., 8 ft., 4 ft., and 2 ft. pitch.

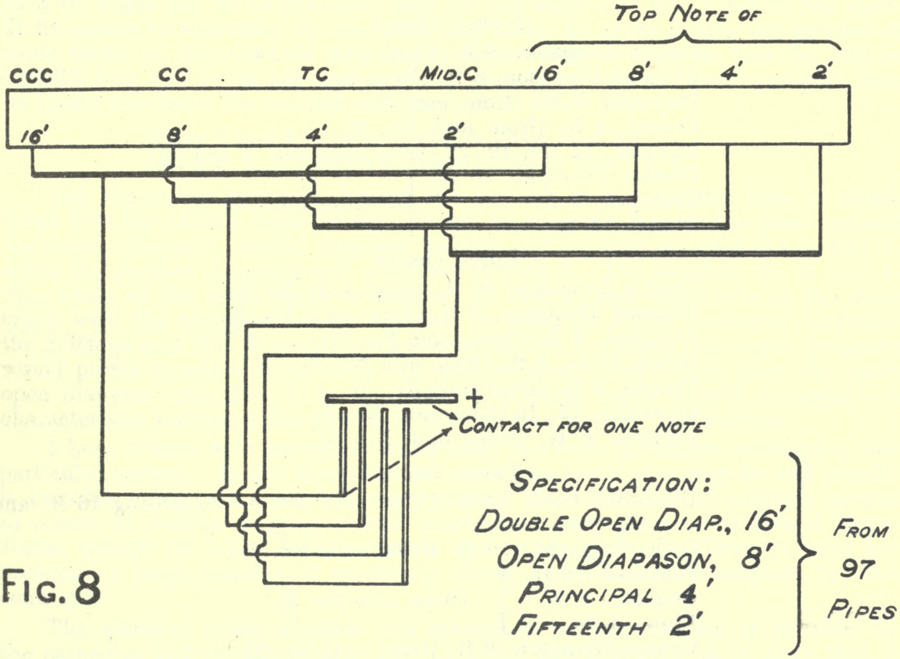

TOP NOTE OF
CCC
CC
TC
MID.C
16'
8'
4'
2'
16'
8'
4'
2'
+
CONTACT FOR ONE NOTE
SPECIFICATION:
DOUBLE OPEN DIAP., 16'
OPEN DIAPASON, 8'
PRINCIPAL 4'
FIFTEENTH 2'
FROM
97
PIPES

FIG. 8

WIRING DIAGRAM OF 97-NOTE UNIT.

To revert to our seven unit ranks above scheduled, we have, as I have said, a common pooling source from which we may tap a specification of stops spread over three manuals and a pedal-board. Many combinations and permutations of tones at various pitches can be devised by the architect in accordance with his particular ideas of tonal design. For the sake of illustration only, and not necessarily to point to the ideal selection from this given unit-pool, I will venture to draw up a stop-list, as follows:—

Great Organ (compass CC to C, 61 notes).
Double Diapason, 16 ft. (from unit No. 2).
Open Diapason, 8 ft. (from unit No. 1).
Open Diapason, 8 ft. (from unit No. 2).
Stopped Diapason, 8 ft. (from unit No. 3).
Quint, 5⅓ ft. (from unit No. 3).
Principal, 4 ft. (from unit No. 1).
Twelfth, 2⅔ ft. (from unit No. 2).
Fifteenth, 2 ft. (from unit No. 1).

Mixture, 19, 22 (from unit No. 2).
Contra Tromba, 16 ft.
Tromba, 8 ft. } (from unit No. 6).
Octave Tromba, 4 ft.

SWELL ORGAN.

Geigen Diapason, 8 ft. (from unit No. 4).
Stopped Diapason, 8 ft. (from unit No. 3).
Dulciana, 8 ft. (from unit No. 5).
Dulcet, 4 ft. (from unit No. 5).
Mixture, 12, 15, 19, 22 (from units No. 4 and 5).
Double Trumpet, 16 ft.
Trumpet, 8 ft. } (from unit No. 7).
Clarion, 4 ft.

CHOIR ORGAN.

Double Dulciana, 16 ft. (from unit No. 5).
Stopped Diapason, 8 ft. (from unit No. 3).
Dulciana, 8 ft. (from unit No. 5).
Nason Flute, 4 ft. (from unit No. 3).
Piccolo, 2 ft. (from unit No. 3).
Quartane, 12, 15 (from unit No. 5).
Tromba, 8 ft. (from unit No. 6).

PEDAL ORGAN.

Resultant Bass, 32 ft. (from unit No. 3, comprising 16 ft. and $10\frac{2}{3}$ ft.).
Open Diapason, 16 ft. (from unit No. 1).
Bourdon, 16 ft.
Gedackt, 8 ft. } (from unit No. 3).
Flute, 4 ft.
Octave Diapason, 8 ft. (from unit No. 1).
Octave Minor, 8 ft. (from unit No. 2).
Dulciana, 16 ft. (from unit No. 5).
Dulciana, 8 ft. (from unit No. 5).
Mixture, 5, 8, 12, 15 (from units No. 2 and 4).
Trombone, 16 ft.
Tromba, 8 ft. } (from unit No. 6).
Octave Tromba, 4 ft.
Trumpet Bass, 16 ft.
Trumpet, 8 ft. } (from unit No. 7).
Clarion, 4 ft.

COUPLERS.

Great to Pedal.
Swell to Pedal.
Choir to Pedal.
Swell to Great.
Great to Swell.
Swell to Choir.
Choir to Great.

NOTE.—No octave couplers required, only unison couplers.
Total number of speaking stops (on the console), 43.

Now as to the enclosing of the various units in swell boxes, we have to exercise a certain amount of ingenuity in order to obtain contrasted effects. If the designer feels very strongly that the great organ diapason chorus from 16 ft. to 2 ft. ought not to be enclosed, then he will keep unit No. 1 out in the open. If he agrees to enclosing all the remaining units, he must decide the number of swell boxes or chambers he is going to have. Let us suppose that he will be content with two boxes (controlled at the console by separate swell pedals): then he might distribute the various units from Nos. 2 to 7 thus:—

Units 2 and 6 to be enclosed in Swell Box No. 1.
Units 3, 4, 5, 7 to be enclosed in Swell Box No. 2.

Let the reader now run through the stop-list once more and note to which Swell Box the various stops belong. It will be observed that on the great manual the double diapason, second diapason, twelfth and mixture are enclosed in Box 1, while the stopped diapason and quint are in Box 2. The trombas are in Box 1. The whole of the swell organ is enclosed in Box 2; also the whole of the choir organ with the exception of the tromba. In order to secure increased flexibility the dulciana unit (No. 5) could be transferred to Box 1. Many unit organ designers would prefer to add a third swell box, and no doubt they would place the main open diapason unit (No. 1) in this box. The pedal organ is well equipped!—a characteristic feature of the extension-unit scheme of tonal architecture.

I hope I have said enough to make clear the basic principles underlying this particular system. In the theatre or cinema organ every stop may be and usually is available on every keyboard in every pitch. The whole idea of multiple service by means of electric coupling contact mechanism may be traced to Robert Hope-Jones, though its fuller development is due to Mr. John H. Compton who has produced a large number of extremely clever and effective examples in this country.

The question arises whether this system of tone-distribution is suitable for the cathedral and church organ. Mr. Compton has endeavoured to show that it is, as witness the organs built by his firm for Downside Abbey and Derby Cathedral—to mention two notable examples. For my own part I should not be prepared to say that such organs are out of place in a church building: I should prefer to say that I am personally in favour of the "straight organ" (as the traditional type is called in contra-distinction to the extension type), although I would not debar the introduction of certain selected extension units in certain cases. If only the one type—whether "straight" or "unit"—were to be built, I should feel that organ building had suffered a definite loss; but speaking generally I do most emphatically advocate the preservation of the traditional great organ consisting of a complete chorus of unenclosed diapason ranks, each member of the family having its complete set of sixty-one pipes from CC to top C.

There are two distinct charges brought against the unit system by its opponents. The first is the "missing note bogey." Take a diapason, 8 ft. and draw sub and octave couplers. Now play tenor and treble C. Next play middle C, and nothing happens. On the pedals only one note is usually played at a time, so that this missing note effect does not matter so much. But on the manuals there would be several missing notes when chords are played under such conditions. The question may thus be put: how can 85 pipes do the work of 183? If, however, a unison rank of pipes is added to the 85 pipes, we now have 146 pipes trying to do the work of 183. It is for the enlightened organist to answer this question. Possibly it does not matter, though many think it does. The other charge against extension and duplication is the lack of tonal variety due to the same set of pipes being utilised over and over again. Take the seven unit or master stops of our three-manual organ above specified: many will assert that however many stops there may be facing the player on the console there are only really **seven**, and not forty-three. The two separate swell boxes admittedly introduce a certain degree of flexibility for the interpretation of modern organ music of the romantic and modern schools, and also for the more effective accompaniment of psalmody in the church services, but there is no real change of tonal characteristic producible from units switched over from one keyboard to another in varying pitch-relationships and strengths. There is undoubtedly some truth in this accusation, but the same charge can be levelled at the straight organ in a multitude of cases. If real tonal variety is the objective of the designer, either he must make the organ very large or else he must sacrifice homogeneity of ensemble and build-up to glaring contrast effects in a moderate size of organ. One cannot have it both ways. It is, of course, quite possible to effect a compromise between the two rival methods of tonal design and to increase the number of independent ranks with the object of introducing a number of fresh qualities into the scheme. Thus, in the above specification we can add an oboe to the swell and a clarinet to the choir, and in order to avoid the vain repetition of the stopped diapason on all three manuals we can add an open flute of 73 pipes from 8 ft. to the top note of the 4 ft. compass: the unison flute on the great can then be a waldflöte or clarabel flute, while the choir octave flute can be a suabe flute. If a celeste effect is desired this must obviously be obtained by the addition of a separate rank of dulciana pipes tuned to beat with the unit rank. String tone is not represented in our scheme, unless we add a further unit of viols, placing it in one or other of the boxes.

What is of supreme importance is to produce an instrument possessing sufficient tonal variety and flexibility to enable a first-class performer to interpret in terms of organ tone all the different types of musical literature that have been provided since the sixteenth century to the present time. This makes a big and varied repertoire and probably no one instrument can do adequate justice to the works of every composer: nevertheless, it is truly remarkable what a player like Lynnwood Farnam could accomplish with apparently limited resources, both tonal and mechanical, when seated at an instrument of classical design and possessing only the one enclosed division. Of course, he would have liked a completer scheme of stops and many more controls, as he had in his own organ at the Church of the Holy Communion, New York. Where funds restrict our liberty in the carrying out of our pet ideas and we are tied down to a galling minimum of pipe-work, it may be that extension and duplication provide the only solution. In that case, are there not certain fundamental rules that the tonal architect should obey at whatever cost? I have stipulated the threefold aim of beauty, pattern and surprise; but it will be asked how we are to know whether an organ so designed is faithful to this triple canon? Take the question of surprise first. This objective is not attained by the introduction of individual tones of abnormal quality or character, since in this event the surprise feature is obtained at the expense of pattern at least. The surprise must reside in and emanate from an ensemble, not a solo effect. Therefore the ensemble must be homogeneous in its total effect and possess a definite personality. A good instance of this is the Father Willis "full swell" effect at St. Paul's Cathedral: it always springs a surprise upon one. Another instance is the full great at Doncaster with its seemingly unlimited wealth of flue tone from 32 ft. to mixtures. It is true that the breaks in the mixtures do not occur at the best places, but the total effect is none the less remarkable. It might naturally be said that a great organ containing so large a number of ranks **ought** to be capable of producing a phenomenal result and that any builder of even ordinary ability could produce an equally fine result from such a superabundance of thematic material. But the history of organ building definitely contradicts this supposition. The greater the number of pipes and stops at the disposal of the ordinary builder the greater the havoc he is likely to make of his material: each pipe is a snare and a trap for the unwary and the self-confident. No; the Doncaster organ might have been a colossal fiasco instead of an outstanding example of tonal architecture. To his eternal credit Edmund Schulze produced a masterpiece. A third example of surprise may be heard in Tewkesbury Abbey, where Michell and Thynne's fine Exhibition organ has stood for some sixty years. Here again, the great organ provides the element of surprise in its soul-stirring diapason ensemble. I refrain for obvious reasons from citing examples by existing firms, though there are many that could be mentioned. We arrive, therefore, at this conclusion in regard to the objective of creating surprise: whatever the means employed, by traditional or unorthodox methods, there must be at least one ensemble effect, diapason or reed, or diapason with reed, that is both beautiful and surprising.

Then there is beauty of tone without which an organ is not a musical instrument in the accepted sense. In the sister art of painting it is well known that the quality of beauty is looked for in the finished product, the total effect of the picture, rather than in the units of colour. But in the organ we expect to hear tones that are individually beautiful (since we wish to use them individually as such) as well as ensembles and choruses that are collectively beautiful. It has been argued that individual stops may be lacking in beauty of tone and yet may in combination with other stops prove their sterling worth in the total result achieved. This is a dangerous theory for the voicer to play with. There is, in my opinion, never any valid excuse for bad voicing or for the production of even one badly voiced stop. It is true that a highly resonant auditorium is capable of transforming that which is intrinsically ugly into an apparent sweetness of quality: that the effect of an organ at the console (if the latter happens to be close to the pipe-work) is quite different from that which is heard in the main building; but there is no guarantee that what is actually bad will appear good in every part of the building, and in any case there is never any need for such tactics. An organ may be boldly treated, diapasons given a greater harmonic development, reeds made more fiery, upper work "let out" more, when the acoustical properties of a building demand it, but the limit which the true artist must always impose upon himself must not be transgressed. There is an excess which engenders vulgarity of effect and irritation in the listener.

Lastly, there is the pattern which the architect has to weave from the materials at his disposal. He may not have all the material he would like to have, yet he must achieve a pattern of some kind. He must build up an art-form and, I would suggest, aim at producing the shapeliness represented by the figures A, B and F of Plate VII. The chromotonic mean pitch-level of the ensemble or chorus he is seeking to create should lie somewhere in the central zone of these figures so as to avoid all possibility of an objectionable hump at either end. The "middle hump" can only be avoided by extension of a not too pronounced unison tone to higher pitches and by the inclusion of mutations. It has been well said that the secret of a successful build-up of units of tone lies in welding together a net-work of tones differing little in respect of power from each other, the object being to create a smooth and graduated concrescence of parts culminating in a personality of ultimate achievement. This was Schnitger's ideal, also Silbermann's. Schulze departed from it in some of his later work, the reason being that he was a born experimenter and his head was full of ideas. At Doncaster, Hindley (as left by him) and Charterhouse, he sought to produce a definite pattern on the old, traditional lines; but at Armley and Tyne Dock he introduced a different mode, more suited in the case of Tyne Dock to a building of cathedral proportions, and actually suited in the case of Armley to the building in which (unknown to this artist builder) the instrument eventually found its permanent home. Was this ideal Father Willis's also? In a sense, yes; for although to Willis the reed chorus was at least as important as the flue chorus—or shall I say, appeared to be?—he was opposed to excess of power in any one rank or unit comprising the main chorus. Cavaillé-Coll most certainly followed this rule in his own style of architecture; and Thomas C. Lewis, in a never-to-be-forgotten conversation with me, enthusiastically endorsed this conception and insisted that he had made it his *credo* during the whole of his career as a master organ builder.

To sum up: if the canonic trinity of objectives—beauty, pattern and surprise—is achieved, need we quarrel with the system which this or that school of organ architect has employed for his purpose? We can only pass a verdict on the result and judge systems by that and nothing else, with the one important proviso that the workmanship is good and the materials are durable so that what is produced may last for a reasonable period of time.

Although the creation of at least two good chorus effects is essential to the modern organ and cannot be accomplished with less than the number of tone-units requisite for the purpose, the claims of the romantic and modern schools of organ tonal design must not be overlooked. What are these claims? Put briefly, they ask for the inclusion of a sufficient variety of special tones for solo use and orchestral or quasi-orchestral effects. There are certain compositions for the Organ which demand for their adequate presentation tones other than diapasons and chorus reeds with or without their supplementary upper work. In short, the organ of classic tradition fails to provide for such music, while the inventive ingenuity of organ builders has added to the organist's palette many new tone-colours of undoubted attractiveness to the average listener. Shall these products of a comparatively modern period in the history of organ craftsmanship be thrown overboard as useless or inartistic?

A lively controversy has recently raged in the correspondence columns of **The Diapason** (the well known organ journal in America) in which the protagonists of the classic and romantic schools of tonal design have put their respective claims before the Editor. I sympathise with both parties, for surely they both have a case. There is no valid reason in theory why the specialised tones beloved by the romanticists should not find an honourable place in the King of Instruments so long as they do not oust a single unit of the essential chorus. The only difficulty—and it is a real one these days—is to meet the extra cost involved in accommodating both types in an economically conceived scheme without detriment to one or the other. I have essayed to solve the problem in my polythematic organ, in which two of the manuals are employed for the basic chorus work of classic design and a third is reserved for stops of specialised construction and tone. In order to make room for this allocation of tonal departments to the three manuals, I have arranged for a "floating accompanimental division" consisting of a selection of suitably voiced stops of moderate strength, enclosed in a separate swell box for preference, which is available on any of the three manuals. I append a specification, illustrating the polythematic idea, giving myself a limit of thirty-seven speaking stops or ranks of pipes.

GREAT ORGAN (unenclosed).

Bourdon, 16 ft.
Open Diapason I, 8 ft.
Open Diapason II, 8 ft.
Hohlflöte, 8 ft.
Quint, 5⅓ ft.
Principal, 4 ft.
Twelfth, 2⅔ ft.
Fifteenth, 2 ft.
Mixture, 19, 22, 26, 29.
Tuba Minor, 8 ft. (from Orchestral).

SWELL ORGAN (in Box (1).

Geigen Diapason, 8 ft.
Stopped Diapason, 8 ft.
Aeoline, 8 ft.
Voix Celestes (T.C.), 8 ft.
Geigen Principal, 4 ft.
Cornet, 12, 15, 17, 19, 22.
Double Trumpet, 16 ft.
Trompette, 8 ft.
Clarion, 4 ft.
Suboctave, Octave, Unison-Off.

ORCHESTRAL ORGAN (in Box 2).

Contra Viola, 16 ft.
Viola, 8 ft.
Violes Celestes (T.C.), 8 ft.
Concert Flute, 8 ft.
Violin, 4 ft.
Zauberflöte, 4 ft.
Piccolo, 2 ft.
French Horn, 8 ft.
Clarinet, 8 ft.
Oboe, 8 ft.
Tuba Minor, 8 ft.
Suboctave Coupler.
Octave Coupler.
Unison-Off
Tremulant to all but Tuba and Horn.

COUPLERS (Unison).

Great
Swell } **to Pedal.**
Orchestral
Swell to Great
Swell to Orchestral
Orchestral to Great

Great.
Accompanimental on { **Swell.**
Orchestral.

ACCOMPANIMENTAL (in Box 3).

Double Dulciana, 16 ft.
Dulciana, 8 ft.
Lieblich Gedackt, 8 ft.
Salicet, 4 ft.
Flauto Traverso, 4 ft.
Octave Coupler.

PEDAL ORGAN.

Resultant Bass, 32 ft.
Open Bass, 16 ft.
Bourdon, 16 ft.
Violone, 16 ft.
Dulciana Bass, 16 ft.
Octave, 8 ft.
Flute, 8 ft.
Viola, 8 ft.
Flute, 4 ft.
Trumpet Bass, 16 ft.
Trumpet, 8 ft.
Clarion, 4 ft.
Tuba Bass, 16 ft.
Tuba, 8 ft.
Tuba Clarion, 4 ft.
Harmonics, 5, 12, 15, 17, 19, ♭21, 22.

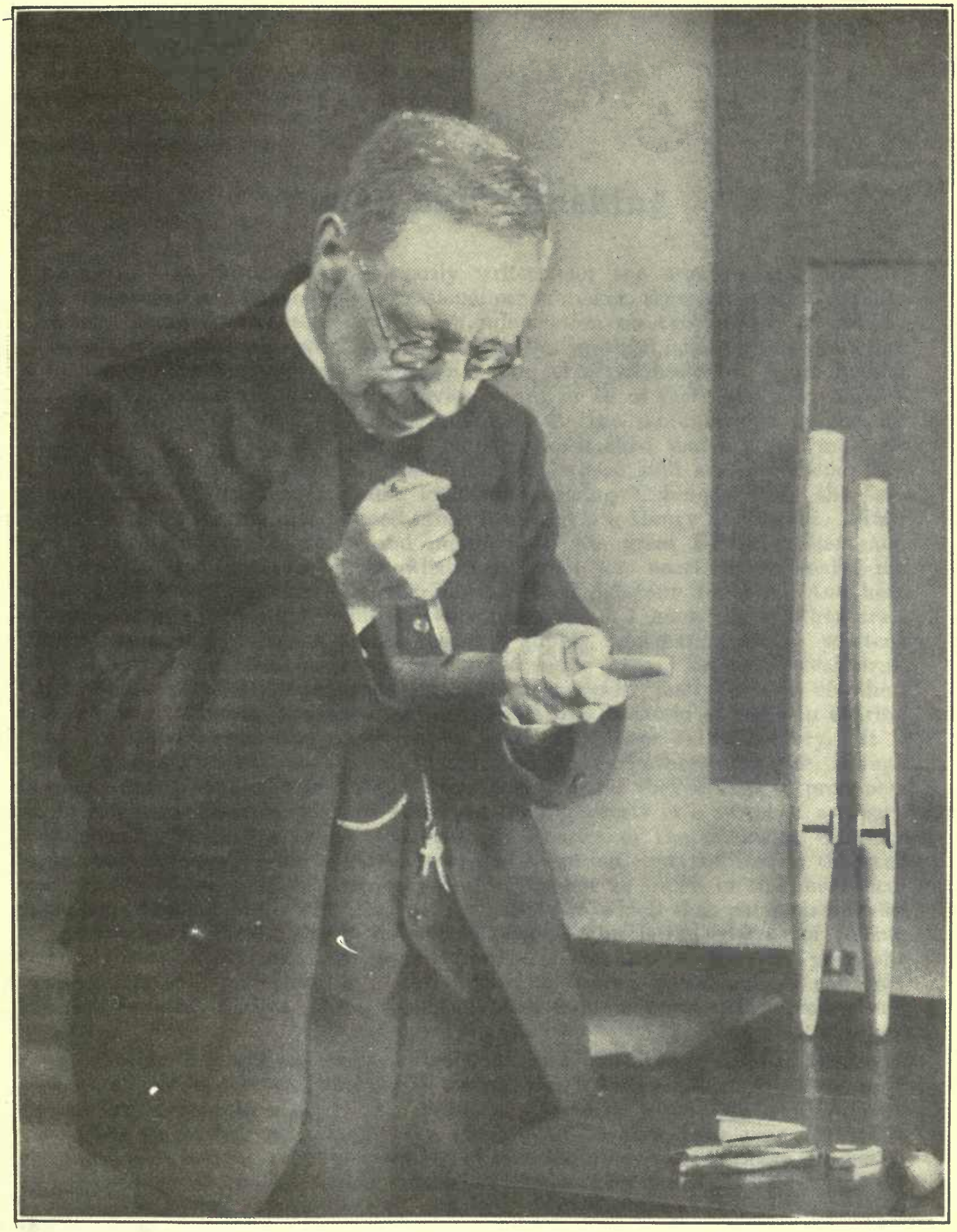
Wind Pressures.

Great flue-work, 3 in. to 3¾ in. (according to circumstances).
Swell flue-work, 3½ in. to 4½ in. (according to circumstances).
Accompanimental, 2½ in. to 3 in.
Orchestral, 4½ in. to all except French horn and Tuba, which are on 12 in.
Pedal Open, 16 ft. (the only independent rank), 3 in. to 3¾ in.

Since I have tied myself down to thirty-seven speaking stops, it will be noted that (1) the whole of the pedal department is either duplexed or extended from existing pipe-work, (2) the great quint is included to complete the diapason chorus independently of the double, (3) there is only one 4 ft. stop on the great, namely the essential principal, (4) there is only one 4 ft. stop (the essential principal) on the swell, (5) the "floating accompanimental" section is given the minimum selection of stops, and (6) the oboe on the orchestral is the orchestral type and not the usual "swell oboe" which has been omitted from the swell organ.

All the stops are assumed to be of complete compass except the two celestes on swell and orchestral respectively. Some organists would have liked a third celeste in the accompanimental section, e.g. dulciana and vox angelica or unda maris. There is no difficulty in devising stop-lists containing numerous ranks of pipes! The above specification is purely illustrative of the polythematic system of tonal design, and I hope is sufficiently clear in its main outline to show what might be done on similar lines by organ builders who desire to meet the demand for an instrument embodying both the classical and the romantic styles of tonal appointment.

There will, I suppose, always be those who prefer the strictly classical type of organ, whether dressed in modern or baroque clothing; while others will never be satisfied with an organ that does not possess the flexibility and expressiveness of total enclosure. A third party will look for orchestral effects in preference to "pure organ tone," forgetting that the King of Instruments is not a "one-man-band." Yet it is possible, as I have tried to show, to find room for the reasonable expression of all these schools of thought in the building of organs without changing the essential character of the Organ of classic tradition.



THE AUTHOR VOICING No. 1 OPEN DIAPASON OF THE ORGAN
AT ST. GEORGE'S CHURCH, KIDDERMINSTER

CHAPTER X

Voicing and Finishing

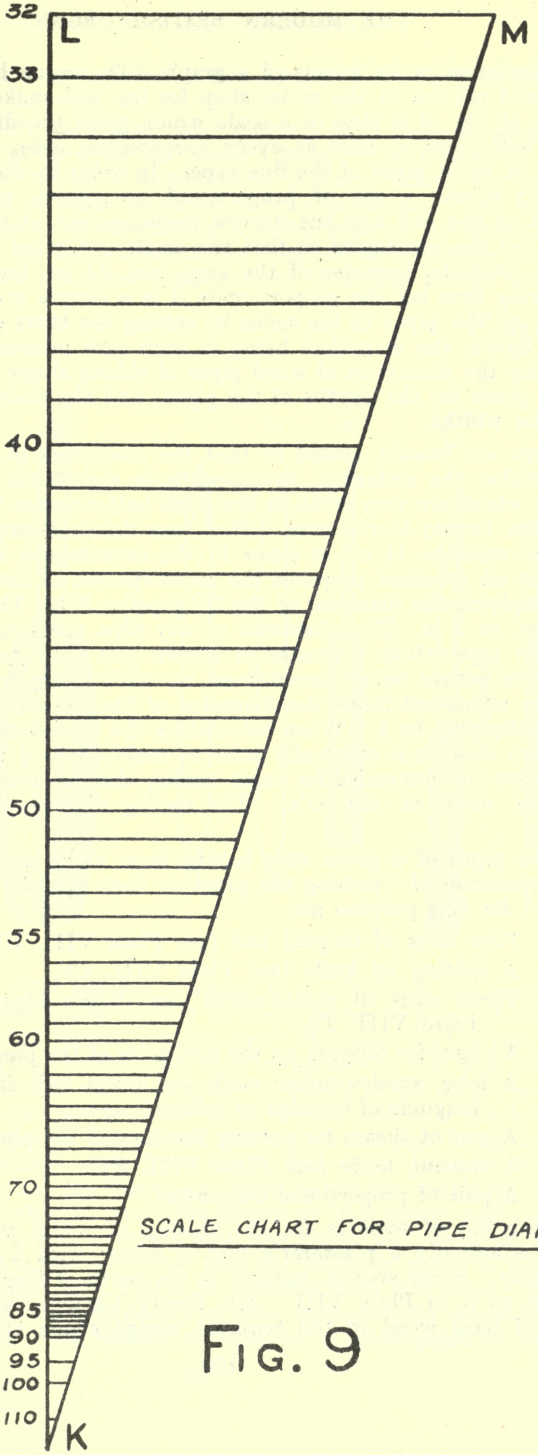
ALTHOUGH this book is primarily written for the organist and amateur enthusiast and not for the professional organ maker, there are quite a number of "home constructors" who seek information on the subject of voicing and regulating pipe-work. There is also the youthful novice whose ambition is to become a voicer and/or finisher in a firm of organ builders. I am hoping that this chapter may be of some service to any or all of these who may happen to read it either for their own amusement or for the more serious purpose of ultimately acquiring the technique. I must make it clear that my own methods are not necessarily the same as those of others whose skill and proficiency are unquestioned. I received my first lessons in voicing technique from the late Frederick W. Pike and also learned much from the late Henry S. Vincent. Since then I have studied the works and methods of the great British voicers and finishers in order to gain such knowledge as I felt was necessary to enable me to assess at their true value the different ideals of different builders. And here I wish to pay a handsome tribute to the profession. I know of no other craft whose professional members are so ready to supply information to the amateur even at the possible risk of a secret method being passed on to a rival firm. Organ builders are not only proud—and in most cases, justly proud—of their methods and products, but are generous almost to a quixotic extreme in sharing their "secret processes and contrivances" with the visitor at the factory. It is a fine spirit that I have not found in the workshops of other industries, though there are exceptions in both cases. It is only natural that a firm of producers or manufacturers should wish to safeguard their interests in a world of competition, and one would have supposed that the queries of the enquiring amateur would be treated with the utmost reserve and caution, but the fact is that the real secrets of the professional organ builder lie not so much in the theoretical paper specification of an invention as in the way in which that particular device or mechanism is carried out in detail and finish. This is indeed true of voicing and regulating organ pipes. It is quite impossible for me to convey in print the secrets of artistic manipulation in this important branch of the art. I can only give the broadest outline of the technical work incumbent on every voicer and finisher.

We must differentiate between "voicing" and "finishing." It has been said that voicing is a craft and finishing is an art; but I disagree to some extent with this rather too precise distinction. What is the voicer's job? It is to prepare the pipes submitted to him by the pipe-maker so that they may (1) speak correctly, (2) give the particular quality of tone required, and (3) **make it possible for the finisher to modify within reasonable limits the precise power and quality of each pipe in the series.** Strictly speaking, it is not the voicer's job to **design** the pipes, to determine the absolute and relative scaling of a given set or stop, to stipulate the wind pressure to be employed, or to decide what in the best interests of the tonal scheme viewed as a whole should be the actual quality of this or that stop. A voicer is not a tonal architect, though he may and often does combine in his person the two offices. Nevertheless, there is room in the stricter execution of his task for real artistry. In proof of this statement I would instance the work of the voicer of diapasons, of string-toned stops and of reed stops. If ever a man needs to be an artist and more than a craftsman it is he who is entrusted with the task of voicing a chorus reed on low pressure. It also takes an artist to voice a geigen or a dulciana. I know of instances where **one solitary man only** was capable of producing a certain kind of quality from a certain kind of stop, and after his death no one could be found to reproduce that man's result. Why? Because he was an artist and not a mere craftsman. There is a nervous expressiveness in the subtle manipulation of the various parts of an organ pipe which is not the common property of all voicers. Some are artists, others are not.

What does the finisher do? He is and must be an artist, if he is to be worth his salt. He is absolutely essential to an organ. He is as much an artist as the greatest of players. His job is to regulate every pipe of every stop so that the desired result may be obtained. He has to determine (1) what stops shall be given what power in relation to other stops: (2) what precise quality each stop shall have: (3) what precise power and quality, within artistic limits, each octave or portion of a stop within its own compass shall have—whether, for instance, a stop shall increase in power in any portion of its compass or its quality be modified in any portion of its compass: (4) how the various tonal divisions of an organ may best be balanced in proportion to one another: (5) the proper relation of flues to reeds: (6) how much to allow in his regulation of enclosed stops for the damping effect of a swell box; and (7) he has to assess as accurately as he can the acoustical influences at work on the organ as a whole before embarking on the task of finishing each stop.

Great masters like Father Willis, Edmund Schulze, Thomas C. Lewis, Aristide Cavaillé-Coll—to mention four that come to mind—were adepts at all the processes of organ pipe manipulation from designing to finishing; but this is not so in all factories—the designer, the voicer and the finisher are three different men co-operating with one another in producing the finished article. In the end, however, the finisher may make or mar the result: and very often, **the building is the ultimate finisher.** There is nothing more uncertain than the ultimate result of the organ builder's efforts: at the most, he can only do his level best, rely on his artistic capacity as designer, voicer and finisher to score a success, or at the worst, to produce a result which all who are unbiassed in their judgment may recognise as possessing the elements of beauty, pattern and surprise.

I will now proceed to the subject of flue-pipe voicing. And first, it is necessary to choose the scales of the stops to be voiced. Reference to chapters dealing with the various categories of organ pipe will enable the reader to ascertain the absolute scales of this or that stop. By absolute scaling is meant the diameter of the lowest C or of any given C without relation to the other C's. Thus the absolute scale of a dulciana stop is 3¼ in. at CC (8 ft.), or we may say it is 2 in. at tenor C (4 ft.) if we prefer to do so—we should, if the lowest octave is to have stopped pipes instead of open dulciana pipes. How are we to ascertain the relative diameters of the remaining pipes in the series? One method is to ascertain the diameters of each of the C pipes from the absolute diameter chosen at CC (or tenor C) to the top C; and then to fill in the intermediate diameters


32
L
M
33
40
50
55
60
70
85
90
95
100
110
K

SCALE CHART FOR PIPE DIAMETERS.

FIG. 9

either by calculation or by means of a graph. The organ builder has his scales all planned and set out in the metal shop for the pipe-maker to use as a guide. The diagram of Fig. 9 is that of a scale which gives the diameters of the pipes so that the half-diameter falls at every seventeenth note. It can be used for either metal or wood pipes of the flue type. In order to work from this diagram it is necessary to use a set of proportional compasses which give the wide measurement at one end and the narrow measurement at the same time at the other end. Set the compasses so that the small end gives L M = 2⅞ in. and the long end the absolute diameter of the stop, viz. 3¼ in. for a dulciana CC pipe (8 ft.). Having thus set the proportioners it is a simple matter to ascertain the diameters of all the pipes in the series by setting the **short** ends to the respective lines in the figure, the diameters being in each case measured at the long ends. In ascertaining the diameters of wood pipes of oblong shape it is necessary to use the scale as given for the **depths** of the pipes, and the scale starting at 35 or 36 to express the **widths.**

Flue stops are usually scaled so that the diameters of the pipes reach half measure at either the sixteenth, seventeenth or eighteenth note, though in the case of viols which are very small in scale the half-measure falls on the twentieth or even on the twenty-fourth note. Thus, our dulciana stop, whose scale at CC is 3¼ in., will measure 1⅝ in. at tenor F (the seventeenth note above CC). We can obtain for all practical purposes the measurement of the tenor C pipe in this ratio by multiplying the diameter of the CC pipe by 3/5. This gives 39/20 in. for the 4 ft. pipe, or 2 in. The diameter of any pipe speaking the thirteenth note above a given pipe whose diameter is known can thus be ascertained, or the diameter of the octave below ascertained by multiplying by 5/3. If the scale halves on the eighteenth note the diameter of the octave above may be ascertained by multiplying by ⅝. When calculating the diameters of the smaller pipes of the top two octaves it is usually safer to multiply by ⅝ than by 3/5; but this procedure is not recommended for exact scaling, only in order to obtain a fair idea of the relative sizes at the C's. The scaling of reed pipes is referred to in Chapter V.

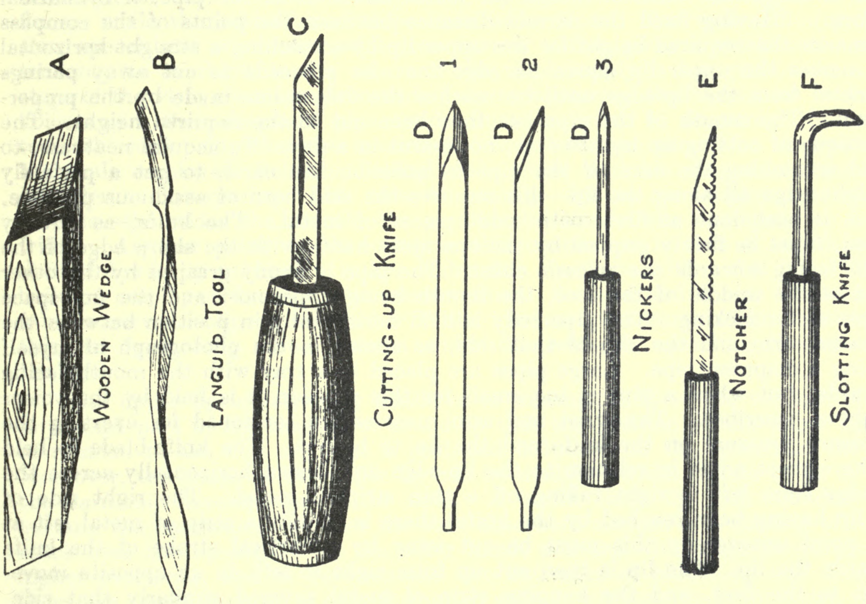
Next, the pipes of a given stop having been made and handed over to the voicer, the operation of "putting the pipes on their speech" is undertaken. The tools required for this purpose are:

1. Four sizes of languid tool (see Plate VIII, B);
2. A cutting up knife (see Plate VIII, C);
3. Three sizes of single-edged and double-edged nicking tools (see Plate VIII, D);
4. A chisel for tapping up the foot-holes of the pipes;
5. A long wooden roller stick (or dowel rod) for tapping down the languids of bearded or rollered pipes;
6. A pair of shears for cutting the tops of the pipes;
7. A slotting knife (see Plate VIII, F);
8. A pair of proportional compasses.

The above list of tools is for the voicing of metal flue pipes only. The languid tool is actually a plasterer's tool of metal with a pliable spade-end at either extremity. Some voicers, notably in the north of England, use the wooden wedge shown at A in Plate VIII. Mr. Henry Vincent used to cut a piece of round stick of hard wood to the required wedge shape at each end which he carried about in his waistcoat pocket. Mr. Arthur Harrison also used wooden wedges.

The cutting up knife should be fixed securely in a stout wooden handle so that it may be firmly grasped by the voicer's hand. The process of cutting up the lips of metal pipes requires considerable practice before the technique is mastered, and the kind of knife employed is very important. Let us, however, see what the voicer has to do in putting a metal pipe on its speech. We will assume that he has at his disposal a voicing machine on which he can test each pipe as it is voiced, and that the wind-pressure from the blower and reservoir is correctly adjusted. (The voicing machine is a miniature one-manual organ, fitted with reservoir, soundboard to hold so many ranks of pipes of various sizes and scales, key action, and blowing equipment). He takes up the pipe and nicks the languid-edge, using the appropriate size of nicker for the pipe in question. The nicking process is carried out by holding the handle of the nicker as one would a pen: the pipe is grasped by the other hand or else held over the bench in the correct position in relation to the voicer, the top of the pipe being towards the voicer and the foot pointing away from him. The space between the languid-edge and the lower lip, i.e. the flue-space, must be plainly visible to the voicer's eye: he must hold the pipe so that light shines on this space, and then he can proceed to make the required incisions with the sharp point-edge of the nicker. This point is pressed into the flue-space and the nicker is made to bite into the languid-edge with just the right degree of pressure from the wrist. The novice must make each incision very cautiously at first, and carefully select the position for each succeeding nick. He should practise on a spare piece of thick metal

PLATE VIII



VOICING TOOLS (FOR FLUE PIPES)

with a bevelled edge before attempting to nick a pipe. It is easy to deepen the incisions later if necessary, but impossible to reduce the depth once the incisions have been made. (Any attempt to do so by burnishing or filing the languid-edge is fatal to the speech of the pipe). If it is desired to nick the languid only and not the lower lip, it is necessary to use one of the single-edged nickers illustrated at D2 in Plate VIII. (Very small pipes are best nicked on the languid only.) The lip can afterwards, if desired, be nicked separately by an upward pressure-movement of the wrist. This also requires practice.

The pipe having been nicked, the voicer next proceeds to cut up the mouth. In order to determine the correct height to which the mouth should be cut, he must take the proportional compasses and set them so that he may measure the ratio of height to width of mouth (or inside diameter of the pipe, if cylindrical in form). Having fixed the correct distance between the points of the compass he marks the required height for the upper lip by scratching a straight horizontal line across the upper lip above its edge-line: he proceeds to cut away parings of metal from the lip-edge until he reaches the datum-line made by the proportioners. The mouth of the pipe has then been cut to the required height. The technique of cutting up is, however, not learnt in a day. To acquire neatness, to avoid scratching the ears (if the pipe in question has ears), to get a perfectly straight edge all along the lip—this requires the skill born of assiduous practice, which is best done at first with odd pieces of metal. The knife, as already stated, must be firmly gripped by the operating hand, with the sharp edge of the blade facing towards the voicer's chest. The pipe is firmly grasped by the other hand at the middle of the foot, the mouth being uppermost and the flue-space visible as for nicking. The pipe-body is held horizontally in position between the operating arm and the ribs of that side, as shown in the photograph of myself voicing a diapason pipe. Large pipes are placed in a tray with the mouth facing upwards; but when a pipe is too small for this position it is held by the voicer as above described. The wrist and arm muscles are tensioned for exerting the necessary pressure on the knife and the lip to be cut. The knife-blade is held at the correct angle in relation to the lip-edge and drawn horizontally across the lip-edge from left to right taking off a thin strip of metal. The right side of the lip having been reached by the knife, there is usually a strip of metal left at this point unsevered: this must be cut away by a **vertical** stroke of the knife towards the lip. The lip is then cut up from right to left, in an opposite movement to the first, and the hanging strip of metal severed similarly that side. This process is repeated until the line representing the correct height is reached. All odd and untidy metal hairs or strips must be cleared away from the lip-edge. It should be hardly necessary to add that the knife should be constantly sharpened up on an oiled whetstone.

If the pipe is intended to give a keen tone it is usual to bevel the outside edge of the upper lip, the precise angle of bevel being determined by the voicer. Diapason pipes are usually given an obtuse and short bevel, while string-toned pipes are given an acuter and taller bevel. This, however, is a matter which cannot be dealt with in detail in any text-book, especially as there is much divergence of opinion about it. Some voicers use the knife for making the bevel, others a chisel, while others, again, prefer to use the sharp edge of the small nicker marked 3 at D in Plate VIII.

The pipe is now placed on its hole on the voicing machine and tested for speech. If it is slow in coming on to full speech either the upper lip should be slightly pulled out by the languid tool or else the languid should be slightly pressed down by the same tool (against the tension of the spade-end). With regard to the latter operation, some voicers use the wooden wedge, while others take a small hammer and a conveniently shaped piece of hard wood or metal and placing the latter on the left side of the languid upper surface tap it down, repeating the operation on the right side so as to keep the languid straight. A dull, insipid, dry tone invariably means that the languid is too low, assuming that the note is not underblown. If the pipe "chiffs" or "spits" before speaking its proper note, the nicking requires deepening, or the lower lip can be nicked if it has not been touched with the nicker in the first instance. The width of the flue is very much a matter for the expert voicer, who knows what type of stop needs a comparatively wide flue and what type ought to have a narrow one. Miniature or echo versions of diapasons, strings and flutes usually have narrow flues, while the bolder-toned stops have wider flues. Too wide a flue produces slow speech and windiness, while too narrow a flue gives a weak note, with a tendency to overblow to the octave if the wind supply is too great. As a rule, stops of the viola class are given wide flues to encourage the harmonics, and many voicers give their diapason pipes wide flues in order to encourage fullness of tone, the idea being that the maximum "body" of tone should be obtained from the scale employed. Schulze disliked wide flues, and his diapasons have quite a moderate flue-spacing, but this is mainly due to his employment of wide mouths—the wider the mouth, the greater the **area** of the flue-space at a given width. Another point worth noting in this connection is that a mouth with a dubbed lower lip requires a rather wider flue than one with a flat lip. The old builders employed flat lips with narrow flues: Schulze and others followed with a more curved-in lip; while Father Willis increased the curve of his flatting, and this last type of lip would take a wider flue without upsetting the speech of the pipe.

The upper lip is extremely sensitive to treatment. Here the vortices play an important part in the making of sound so that the position of the upper lip-edge in relation to the flue exercises a profound influence on the speech of the pipe. Moreover, the shape of the upper lip can be modified within limits so as to affect the harmonic development of the note. A blunt, thick lip with rounded edges curtails the harmonics: so does the soft, absorbent surface of a coating of leather stuck over the lip-edge. On the other hand, a sharp, thin edge encourages the higher overtones, and in between the two extremes of bluntness and sharpness there are many variants of edge-formation with or without the bevel which modify the tone of the pipe in the subtlest manner. The voicer has to use his own discretion as to the precise degree of modification he deems best calculated to produce the tone he wants. Generally speaking, if the upper lip is drawn out, the lower lip may be drawn out as well; but it does not follow that this is the correct thing to do: it only means that the pipe will speak promptly and not fly up to a harmonic—what **tone** it will give is another matter.

As regards the technical manipulation of the lips and languid, the languid tool (the wooden wedge type or the metal plasterer's tool) may be used for all these operations. The raising of the languid makes the pipe slower in speaking, while the depression of the languid makes the pipe quicker. To raise the languid it is necessary to insert the spade-edge of the metal tool (or the edge of the wooden wedge) between the lower lip and the under-surface of the languid and lower the other end of the languid tool so that it acts as a lever. The metal tool does no harm to the languid since the spade-ends are flexible; while the wooden wedge is sufficiently soft in its contact with the metal surface of the languid to shift it without injury. After each operation has been carried out, as above described, the pipe must be tested on the machine for speech and quality of tone, till finally the voicer is satisfied with the result of his labours.

There are various little dodges which voicers resort to on occasion, such as "tucking in the corners" of the flue by tapping in each side of the lower lip towards the languid, or slightly altering the position of the ears, or slightly arching the upper lip instead of increasing the height of the mouth along the entire width of the lip. But these are minor points compared with the major operation of voicing.

I have left to the last the highly important adjustment of the foot-hole. Obviously, the quantity of wind admitted to the foot of a pipe at the pressure supplied by the soundboard pallet is a vital factor in the speech, quality and power of the pipe, which is very sensitive to changes in its wind-supply. It is therefore necessary for the voicer to determine at the outset what power the stop ought to possess so that he may adjust the size of each foot-hole in the series in due relation to the tonal result aimed at. I have said that the actual power of a stop rests ultimately with the finisher, so that the voicer cannot have the last word in this matter. But he must so treat the pipes that a working margin is available for a reasonable degree of modification in the direction of greater or less power in the final regulation. To this end the voicer usually keeps the foot-holes on the small side so that if required they can be enlarged without detriment to the proper speech of the pipes. I would not be misunderstood here. There is no question of underblowing the pipes in this precautionary step: the margin allowed for enlargement is quite small really, but it is there. If the foot-holes are given the maximum permissible size there is the risk of certain pipes in the series failing to speak properly when transferred to a different chest or soundboard: indeed the whole stop may function differently on another set of pallets unless a margin of safety is provided. In any case the pipes must speak **easily** without the least trace of forcing, and this condition is best served by making the foot-holes **slightly** smaller than is required for full speech.

The operation of enlarging the foot-hole is by paring out strips of metal from the inside perimeter of the toe of the pipe. Care must be taken to avoid leaving the extremity of the foot with a sharp edge round its perimeter due to the thinning process performed by the knife: sharp edges must be trimmed and the toe left in proper shape. A cupping tool may be used if desirable for restoring the curved-in shaping, but this diminishes the foot-hole, and it will be necessary to enlarge the hole once more. The hole is reduced by tapping all round its outer perimeter with a flat chisel, turning the pipe round all the time in order to ensure a uniform surface at the toe-end. Dulciana pipes are very sensitive to this tapping operation, especially below treble C, and only a few taps should be given before the pipe is tested on the soundboard: the same sensitiveness is exhibited in the enlarging of the foot-hole which must be done very carefully. Some voicers insert a narrow tapering tool into the foot of a pipe of this type in preference to cutting with the knife. For the larger pipes such a tool is not recommended because it invariably leaves a sharp circular edge which has to be trimmed, thus wasting time and labour, and moreover tends to burst the solder-joint of the foot.

Pipes fitted with beards or with roller-bridges require certain other voicing tools besides those already mentioned in connection with the ordinary type of pipe. After the roller-bridge has been duly fitted and fixed between the ears, the languid may need raising or lowering for perfecting the speech of the pipe, and this is best accomplished by tapping the top surface of the languid with a narrow ramrod of wood sufficiently long to reach the languid when inserted through and down the top of the pipe. The languid is tapped at each side on its front edge till the desired position is obtained. To raise the languid a stout wire may be passed up the foot of the pipe and the under-surface of the languid tapped upward at each side at its front edge. Alternatively, the bridge may be removed and the languid tool applied in the ordinary way; but it is a nuisance to have to remove and re-fit the bridge once it has been correctly fixed. The voicer usually takes care to see that the languid is not too low before he fits the bridge: he will then only need to tap the languid down from the top of the pipe if necessary.

The voicing of very small pipes, such as those which belong to the upper octaves of the 4 ft. and 2 ft. stops, requires the "surgeon's skill" and very sharp tools for cutting and nicking. The larger pipes, such as those in the 8 ft. octave, are not really difficult to manage if one uses the right tools for nicking and cutting up. It is obvious that various sizes and gauges of languid tools are necessary for working on the widely differing sizes of languid and mouth-parts which confront the voicer of a complete family of diapasons, strings or flutes.

The slotting of a metal pipe is done with the scoring tool shown at F in Plate VIII. This tool is held vertically with the hooked portion uppermost, and the scoring point is drawn across the pipe's surface first with a straight downward stroke (repeated several times till the metal is cut through all along that vertical line), then with a similar downward stroke parallel to the line already cut at the correct distance to the right of it. When both lines have been cut through, a third line is cut horizontally at the top of the other two, bridging them and enabling the operator to pull open the now free strip of metal as far as required. The top line is measured at the pipe's diameter from the top of the tube. The difficulty in the operation lies in getting a straight vertical cut down a cylindrical tube, and it is necessary to use the thumb and first or second finger of the operating hand as a guide for the knife, keeping these fingers in contact with the sides of the pipe-body all the time during the down stroke. The tyro is strongly recommended to watch an expert craftsman performing the operation before he attempts it himself.

The final task devolving on the voicer is that of regulating the pipes of the complete stop and then tuning them. He can only give them a rough finish at this stage because he has to cut them down to length so that they can be fine-tuned by means of the tuning slides or the cone. (All metal flue pipes from 4 ft. to 1 ft. length ought to be fitted with tuning slides, the only exceptions being made in the case of pipes with conical or inverted conical bodies: pipes above the 1 ft. can be cone-tuned.) A tuning fork is necessary for ascertaining the correct pitch for the stop under treatment. It is good practice to have on the voicing machine a set of principal pipes fitted with extra long slides, which can be tuned to the required pitch before the stop to be voiced is taken in hand. The first pipe handled and put on its speech should be tuned **flat** to the corresponding principal pipe, being cut down sufficiently for this purpose; and so on for the rest of the pipes. After the voicing operations have been completed, the pipes should be further cut down and left **sharp** to the principal to allow for cooling. After waiting for a period of a quarter of an hour or so to let the pipes cool, the voicer may tune the whole stop to the principal by means of the slides or the cone, again cutting down where required. Finally, he must run through the stop, pick up any minor faults, and regulate for uniformity of strength.

Some voicers are much quicker than others in carrying through the complete process above described—very inadequately, I fear—but it by no means follows that the slow workman is an inferior artist. It so happens that Thynne was not a quick worker and was known to take a full week over the voicing of one viol; the explanation being that he was never satisfied with the result of his efforts till he had gone through every pipe over and over again.

Having dealt with the treatment of metal flue pipes, I must now turn to the voicing of wood pipes. The success of a wood stop depends to a large extent on the wood pipe maker, since there is no means of raising or lowering the languid (or block) or of moving the upper lip in or out. These positions are determined once and for all by the pipe-maker, and the voicer has the task of (1) notching the block and/or the cap, (2) fitting the cap in relation to the block, (3) altering the slant of the top inside surface of the cap, (4) plugging the foot-hole, and (5) fitting, if required, the roller-bridge or the beard. Occasionally, he may have to cut up the mouth.

The block is notched (or nicked) as shown at L in Plate II, using the notching tool shown at E in Plate VIII, which is a small saw and is applied to the front surface of the block, the pipe being placed on the bench with its top facing the operator. The cap may also be notched separately, though it is often left with the inside edge smooth and flat. In the case of pipes with inverted upper lips both block and cap should be well nicked. If the cap is set flush with the top surface of the block, as shown at A, D, E, F, G in Plate II, no nicking is required; but if the cap is set a little below the block as shown at B and C, nicking is indicated and is imperative on the block-face at least. In the treatment of string-toned pipes Pendlebury used to chamfer the front top edge of the block and set the cap below the chamfered edge (as shown at H in Plate II), nicking both cap and block in imitation of the metal lip and languid: the windway (flue) was blackleaded and polished.

The top inside edge and surface of the cap is usually made flat and vertical: it is only slanted back (away from the block, as illustrated at G in Plate II) when it is desired to obtain the maximum of upper harmonics from the pipe. The middle inside portion of the cap may be cut out as shown at A and D in order to increase the head of wind at the flue, or it may be given a top curve as at B and C for the same purpose. An all-flat surface as at E and F is invariably off-set by a backward slope formed on the front surface of the block, which helps to concentrate the head of wind on to the flue in an outward direction. It will be noticed how the maximum space is provided in the "throat" (or intermediate air chamber between foot and flue) in Pendlebury's pipe at H.

The cutting up of the mouth is done with the same knife as used for metal pipes, though some voicers prefer to use a sharp chisel and finish off with a knife and a file. If, however, the pipes have been constructed at the bench with precise instructions from the designer there is seldom any necessity for altering the height of the mouths, and the pipes are regulated for power and correct speech by plugging the feet. Zinc feet are sometimes provided instead of the more usual wooden ones, in which case the foot-holes are treated as in the case of metal pipes. Wooden pipe-feet are plugged with small pieces of hard wood, which are wedged in the foot-hole and tapped flush with the bottom end of the foot. First a wedge is inserted in the centre of the hole, dividing the circle in equal halves: then a second smaller wedge is fitted at the side of the first at right angles, and thirdly another wedge of the same size fitted at the opposite side, thus forming a cross or plus figure. Further sticks of wood can be plugged in the remaining crevices as required, leaving only a very narrow space for the wind to pass through. In this way, the size of the foot-hole ("coefficient of discharge") can be regulated from maximum to minimum as required. The feet of large pedal pipes should be fitted with throttle-valves to facilitate regulation of the wind-supply without removal of the pipe. The John Compton Organ Company have an ingenious focussing device similar to that used in photographic cameras which reduces the circumference of the hole uniformly all round from maximum diameter to zero. The time will doubtless soon come when the feet of smaller wood pipes will be made of a suitable plastic material.

The voicing of reed pipes must now claim our attention. The **technique** of reed voicing is centred on the curving of the tongues. First, however, the voicer has to choose a set of shallots suitable in shape and size for the particular stop to be voiced. He may select any pattern from those illustrated in Plate IV—B and D for smooth reed tone, C and G for fiery reed tone, E for moderately free tone, and F for the thin-toned reed (such as the orchestral oboe). The pipe-maker will have supplied the voicer with the basic parts of the reed pipe, viz., the block, boot, and tube or resonator: the voicer has to supply the shallot, tongue, wedge and tuning spring for each pipe in the series. The shallots are provided for him by the shallot-maker, and all he has to do is to select the appropriate type for his purpose, laying them out in due order on the bench so as to have them ready for fitting into the block-holes in the under-surface of the block (see A in Plate IV). The tongues are cut out to the correct shape and size from brass sheet which has been planed dead smooth and made perfectly flat. Various gauges of brass sheet are prepared from which to cut the tongues so that they may be of the correct thickness for each set of pipes. The voicer takes a strip of prepared brass sheet of the required thickness, equal in width to the length of the longest tongue to be cut out, and then marks off the tongues side by side, head end followed by tail end in succession; he next scores off the tongues with a cutting tool such as the slotter shown at F in Plate VIII. When scored nearly through the tongues can be broken off with a pair of pliers: (if they are cut off with a shears they curl up at the edges). They are then finished by being filed and sand-papered on both sides. If a tongue is too wide for the shallot, it must have its edges planed to the exact width of the shallot-face, the tongue being placed in a vice (with jaws of hard polished wood) with the edge protruding at the side of the vice. Long, large, thick tongues are often "dressed" with a small hammer on a polished metal block so as to get them perfectly straight. The head of the tongue is sometimes made slightly thicker than at the tip (or narrow end), but this is quite unnecessary.

The tongue is placed flush with the face of the shallot so as to cover it exactly. I have seen the tip end of a tongue projecting quite half an inch beyond the tip of the shallot so that the tongue enters the opening of the tube or resonator. This is very bad indeed, since the air waves cause this projecting end to vibrate and set up parasitic frequencies disturbing the tone of the pipe. The tip of the tongue should never project more than an eighth of an inch into the block-hole beyond the tip of the shallot.

The tongue is clamped to the shallot by means of a small wedge cut to the required shape from a piece of hard wood. One method is to sharpen the end of a length of cylindrical stick leaving the under-surface flat: this stick is then fitted into the block-hole with the shallot in position and rammed in with a few strokes of a hammer or chisel. The stick is next chiselled round its upper surface starting at a point about three-quarters of an inch distance from the block. When the appropriate shaping has been given to the upper surface of the stick the untouched portion is cut off leaving only the wedge. The wedge is then extracted by the pliers; the tongue is fitted on to the shallot and clamped securely in position by the wedge, the latter being tapped in tightly by a chisel. In order to remove the wedge with the tongue in position it is best to use a chisel and to lever the wedge out. Some builders use metal wedges, and these are to be preferred to wooden ones: in hot climates the metal wedge is essential.

The tuning spring (or wire) is best made of phosphor bronze. Un-annealed steel wire was at one time regularly employed, but in damp buildings the wire rusts and tuning becomes a problem. I have had no end of trouble with steel wire tuning springs in the past, which have become firmly fixed in the block instead of sliding smoothly as they should do up and down the tongue surface. The formation of the spring is shown at A in Plate IV: the wire is fixed in the vice and bent to shape with the pliers, the crook that slides along the tongue being made first, then the V-shaped bend, and lastly (**after** the wire has been passed through the tiny hole in the block) the tuning crook (bent at right angles to the vertical).

Care must be taken to see that the shallot lies square in the block. In Fig. A (Plate IV) it will be noticed that there is a short projecting piece at the bottom of the block, marked "Y": the head (wide end) of the shallot, as viewed by the voicer's eye with the pipe facing him horizontally, must be square with this section of the block. If it is not, the shallot must be adjusted to the correct position. If, on examining the shallot of a reed pipe with the tongue clamped in position, it is found that the shallot has shifted slightly, it is permissible to adjust the shallot without removing the tongue and wedge by means of the pliers, provided that the pliers are made to grip the **narrow** end of the shallot and not the wide end (i.e. as close to "Y" as possible). The head of the shallot should never be tapped with the chisel or hammer, but with a wooden tool such as the flat wooden end of a tool handle. The tongue must also lie perfectly straight on the shallot and not protrude at any point through careless placing or clamping. **No dirt or dust of any kind, and no moisture, must on any account be allowed on any part of the tongue or shallot.** The shallot must be absolutely clean and clear inside, and so must the resonator and the boot. It is well known that reed pipes must not be blown by the mouth because human breath is moist and moisture is the reed's deadliest enemy. Suction applied to the open end of the tube is, however, harmless **if** it is desired to try the note of a reed pipe in this way.

The curving of the tongues is the voicer's next duty. For this operation a block of hard wood is used, and a burnisher. These are illustrated in Fig. 10. The tongue is clamped on the block, as shown, and the burnisher (which may be a cylindrical steel rod 3/16 in. thick with a wooden handle, or shaped as in the illustration) drawn along the surface of the tongue with a quick stroke of the wrist and arm. Some voicers hold the block with the left hand and tilt it up slightly so that the surface is inclined downwards from the waist-line of the voicer's body: with the other hand they burnish the tongue from fore to aft, "aft" being slightly lower than "fore." Others lay the block on the bench and operate as shown in the sketch. The important part of the technique is, of course, the manner in which the burnishing stroke is performed. This I cannot convey adequately in words—it has to be acquired. I would stress, however, the following points: (1) the stroke must be performed rapidly: (2) a graduated

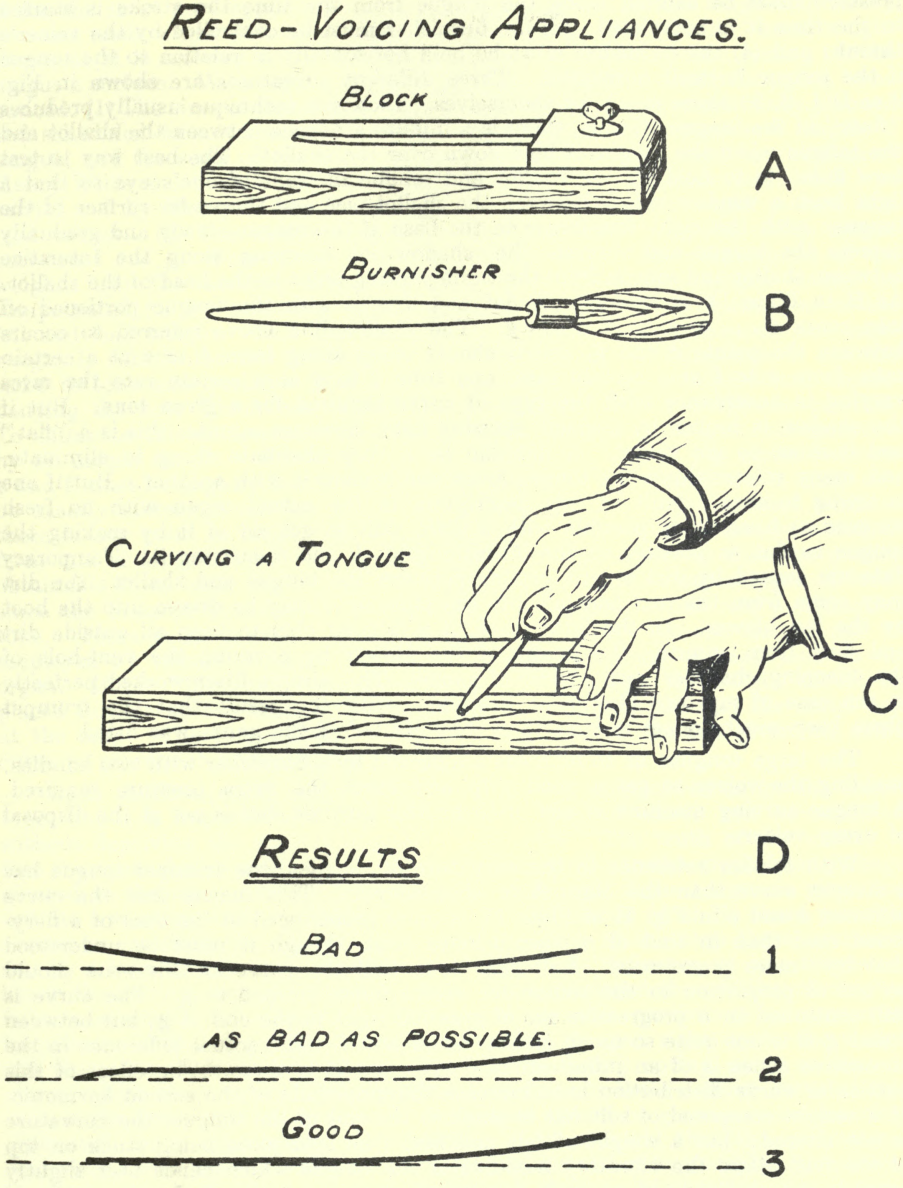

REED-VOICING APPLIANCES.
BLOCK
A
BURNISHER
B
CURVING A TONGUE
C
RESULTS
D
BAD
1
AS BAD AS POSSIBLE.
2
GOOD
3

FIG. 10

pressure must be exerted along the tongue from the time the stroke is started to the time it is completed: (3) the burnisher must be controlled by the voicer's **thumb**; and (4) the burnisher must be held horizontally in relation to the tongue if the tongue is itself horizontal. Three different curvatures are shown in Fig. 9 at D 1, 2, 3: these speak for themselves. Incorrect technique usually produces "flats" in the tongue; that is, there is a minute air-space between the shallot and the tongue when the tongue is held down over the shallot. The best way to test for "flats" is to hold up the shallot and tongue in front of one's eye so that a light from a window shines between the shallot-face and the under-surface of the tongue: with the right fore-finger on the base of the tongue slowly and gradually depress the tongue and observe the shadow-line creeping along the interstice between shallot and tongue from the tuning spring point to the head of the shallot. At H in Plate IV is shown a shallot and tongue with the tongue portioned off into zones **d . . . e, e . . . f, f . . . g**. The shadow-line above referred to occurs between the points **d** and **g**, and it should creep along from **d** to **e** at a certain rate, from **e** to **f** at a certain rate, and from **f** to **g** at a certain rate **the rates varying in accordance with the type of curve required for a given tone.** But if the shadow is broken by a space, **showing light**, however minute, this is a "flat" and it must be got rid of. A flat can be a very obstinate thing to eliminate, and many voicers throw the tongue away and replace it with another. But if one is trying to cure a fault of this description in the actual organ with no fresh tongues at hand, it is possible with a little skill to get rid of it by making the tongue as flat as possible on the burnishing block and re-curving it. Temporary flats are caused by dirt or grit getting between the tongue and shallot: the dirt may come from the roof and fall into the pipe, or it may be driven into the boot by the fan blower. In the latter case, it is a good plan to keep all outside dirt and dust from entering the intake of the blower by covering the vent-hole of the silencing chamber with a strip of gauze. This simple filter worked perfectly in the case of my own blower at Stagsden, with the result that the trumpet pipes keep much longer in tune than they did before the gauze was fitted.

The large tongues of 16 ft. reeds are curved by a burnisher with two handles, enabling the voicer to get a good grip and exert the extra pressure required. A tongue-curving machine is also used for this purpose, but is not at the disposal of every voicer.

With further reference to the curvature of tongues, the trumpet tongue has a steeper curve than the clarinet or oboe tongue. This means that the curve between **d** and **e** in Fig. H of Plate IV is more pronounced in the case of a fiery-toned reed than in that of a smooth-toned reed, though it must be understood that by "more pronounced" I do not mean that the curve at this zone should be out of proportion to the remainder of the curve from **e** to **g**. The curve is still continued in a progressive arc of gyration right to the end at **g**; but between **f** and **g** it is not quite so much as between **e** and **f**. The actual difference in the successive zones is of an infinitesimal degree, yet it is there. The effect of this particular curve distribution is to increase the amplitude of the second harmonic. If a weight composed of soft felt is stuck to the end of the tongue, the curvature is not altered; but a weight of felt and lead (the lead piece being stuck on top of the felt) alters the vibratory modulus of the tongue which bends over slightly towards the shallot-head at each downward stroke and therefore necessitates a slight increase of curve between **f** and **g** to allow for this. As explained in Chapter V, reed tongues are not weighted unless the voicer feels that they are too "free" in vibration and need the weight to curb their activity: consequently, weighting is for the most part applied to the longer tongues and to the tongues of heavy pressure reeds which otherwise might be over-driven. The "Willis" brass weight shown at H is screwed on to the tongue, with the conical portion resting on the tongue's surface. With regard to this type of weight there are certain points to be noticed. (1) The sizes of the weights are all most carefully and scientifically planned and scheduled to suit the wind pressure employed, the thickness and length of tongue, and the scale of the tube: in short, they are standardised by the firm of Henry Willis and Sons for the use of their reed voicers. This standardisation was carried out by Henry Willis II, one of this family of great organ makers and reed voicers. (2) The weight must be screwed to the correct point of the tongue between **f** and **g**. There must be an open space under the conical point of the weight. (3) The bending action of the tongue due to the weight cannot be compensated for by increasing the curve between **f** and **g**, as in the case of the felt and lead weight. This explains why, if a brass weight of exactly the same weight is substituted for the felt and lead weight, the resulting note is not the same in tone and quality: usually there is a buzzing and rattling sound accompanying the note which was absent with the felt and lead weight in position. To eliminate this disagreeable effect requires re-curving the tongue, an operation by no means simple. However, it must suffice to say that the curve between **e** and **f** must be slightly increased, and that the curve between **d** and **e** must also be exactly correct in relation to the remaining curve. It may be asked whether there is any point in employing brass weights if a smooth tone can be obtained from one of felt and lead with far less trouble. The answer is that the quality obtainable from brass loading is **not** the same as that from other types of load, since the brass produces a formant of its own and imparts to the reed a distinctive tone. There is no reason, however, why both loading systems should not be employed by voicers in order to introduce different types of reed tone in an organ. If the "filled-in" type of shallot (see B) is used, the weight should be placed further up the tongue so that its screw-point may not foul the metal cap at the base. The unweighted extremity of the tongue is then given an extra curve to prevent it from striking the cap.

Open shallots (see C and G) may have their tongues curved as for the closed type, but it is important to note that the "trumpet" curve can be modified without depriving the reed of its upper harmonics. The truth of the matter is that the open shallot encourages parasitic overtones due to the much freer passage allowed to the air waves during tongue-vibration, and if the tongue is given too definite a starting curve at the point of the tuning spring (**d** at H) these parasitic overtones are given full play. In the treble portion of the stop these overtones can to a large extent be masked by the controlling influence of the resonator, but in the lower octaves the resonator loses this control and the addition of weights fails to eliminate the overtones. The reason for this persistence of unwanted frequencies in the larger pipes is that the shallot is open right up to the wedge and the pressure of wind is able to disturb the tuning spring point so that it vibrates with the tongue. **The only true remedy is to avoid a steep curve at this zone in the lower octaves.** In short, the tongue should be given a more smoothly graduated curve approaching the parabola. I should add that the professional reed voicer does not rely solely on the block and burnisher for finishing his curves; he slips a thin knife-blade between tongue and shallot and runs his thumb along the upper surface of the tongue—the tuning wire being pushed right back to the wedge or else removed—and in this way he is able to make the most minute adjustments to the curvature at any desired point of the tongue. In fact, this "finishing technique" is essential to the best results, and is only acquired by very few voicers.

As soon as the tongue of a reed pipe has been curved and set in position, the note must be tested on the voicing machine. If the pipe refuses to speak, the tongue is over-curved and must be reduced—a none too easy matter for the beginner, since attempts to reduce the curve usually result in producing a flat. However, there is no harm in making the attempt by removing the tongue and burnishing it on its reverse side, or by burnishing the tongue in position (without removing it) with a thin metal rod or stout steel wire or the small blade of a pocket-knife, at the same time holding the extreme end of the tongue firmly down against the head of the shallot and reversing the normal curving process by starting from the head end. If the note is slow in speech (and this can be proved beyond question by sounding a flue pipe with the reed pipe simultaneously), again the tongue needs reducing. If the note is prompt in speech but poor in tone or weak, the tongue is insufficiently curved. Some voicers then (presumably to save trouble) insert a thin sheet of stiff paper between the tongue and the shallot as far as the tuning-spring point and thus increase the curve. Sometimes this does the needful, since it may be that the curve wants increasing at the tuning point; but I do not advise such a procedure in normal circumstances. It is far better for the novice to remove the tongue and give it an extra curve on the burnishing block.* Before it is replaced the set of the tongue should be scrutinised by the eye by holding the reed up to the light as previously explained. Care also should be taken to replace the tongue so that it is set perfectly true, with the tuning spring dead square on the tongue, and the tongue securely wedged.

Assuming the speech to be satisfactory, the voicer must get the pipe in tune to the principal. The correct procedure is to tune the tongue by means of the spring so that the pipe gives the quality of tone desired, and then to see how far that note deviates in pitch from the pitch of the corresponding note of the principal (an octave higher). It will in all probability be found that the reed note is flat to the principal, which means that the tube or resonator must be cut down till it is of the required length to enable the tongue to be tuned dead to the principal without any sacrifice of the optimum tone. Knocking the tuning spring down will raise the pitch of the note but make it duller in tone, while tapping the spring up will lower the pitch but make the pipe louder and more brilliant in tone; it is obvious, therefore, that the length of the tube must be adjusted to suit the tone and power required. After all the pipes have been cut to the correct length, the voicer must give them a rest and allow them to cool. When he returns to the job he will find that the pipes after cooling will need further cutting, but instead of cutting them he will do well to slot them at the top of the tube: he can then adjust the slot opening of each pipe as a final operation.

The question of the accurate gauges to be chosen for the tongues of a complete stop is too technical for a book of this kind, as is also the grading of the shallot sizes. The amateur must be content to leave these matters to the expert pipemaker and voicer. I do, however, know of one amateur enthusiast who makes his own shallots and in fact every part of the reed and flue pipe, metal or wood, with a finished perfection which can be excelled by no living professional. Readers of this book may be able to guess his name before the last chapter has been perused.

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* The practised technician will apply the knife between tongue and shallot.

An important point in reed voicing is to see that the tuning spring is not too close to the wedge or too close to the head of the tongue after the note has been finished on the machine. If it is too close to the wedge it is obvious that the tongue is too thick for that particular pressure and pitch; and if it is too close to the head of the tongue, the gauge is too thin. Or if the tongue is weighted and the vibrating length too short, it is too thin or the weight is too heavy.

The boots of reed pipes speaking on less than 7 in. pressure and from 4 ft. up often have small holes bored in them. The object of this device is to damp out the resonance of the air-column in the boot which may adversely affect the tone of the pipe. Reed pipes which are liable to "choke" when tuned on the close side in order to produce a smooth tone can sometimes be cured by means of this small hole in the boot: I refer more particularly to such reeds as the clarinet and the horn-type oboes.

The various devices and appendages applied by voicers to reed tubes, and the various types of reed stop found in organs have been described in earlier chapters.

A few words on the subject of "finishing" will conclude this chapter. It takes two men to carry out this important operation, the artist at the keys and the voicer at the pipes inside the organ. It cannot be too strongly urged that the man inside should be an expert **voicer** and not an ordinary tuner. It makes an enormous difference if the man who makes the small but necessary adjustments to the pipes is himself an artist working under and at the same time co-operating with the finisher at the console. Nothing, from the finisher's point of view, is more exasperating than to be giving directions to a man in the organ who is not an accomplished adept at his job. The regulation of the strength of this or that pipe is a simple matter, but not the regulation of the tone and speech. If the man inside is unable to get a particular pipe right or to the satisfaction of the finisher, the said pipe must be passed out to the finisher (who must also be an accomplished voicer) to deal with. This takes time and with a really expert voicer inside would be rarely necessary. It is obvious that all final regulation must be carried out in the actual building and not in the factory, since the acoustics of the building and the situation of the pipe-work profoundly affect the tone of the organ and the blending properties of the various stops. For instance, in a resonant building the fundamental and lower harmonics of pipes are more in evidence than in a non-resonant building in which high-pitched tones are relatively more pronounced.

It is impossible for me to deal here with the subject of regulating the strength and quality of this or that stop so that it may match or combine with other stops. In the chapter in tonal architecture I have tried to indicate the lines on which such work should or may be conducted. But **how** this process may be achieved by the artist finisher cannot, I submit, be expounded in any textbook. I shall, therefore, offer some hints, for what they are worth, as to the method by which a given stop may be fine-regulated at the console **in the building.**

First of all, let the finisher play a rapid chromatic scale over the complete compass of the stop to be regulated so as to gain a broad idea of its general tone, power and function in the tonal scheme of the instrument. Then, let him take the middle octave only, middle C to treble C, and play quite slowly the chromatic scale within this octave of notes. Does middle C satisfy him in strength? In speech? In quality of tone? If not, does any other note in this octave come completely up to expectation? In short, he must fix on one note **nearest to the middle C note** which satisfies him completely. This is his model to which he can adjust all the others in that octave. (There will probably be several notes which are equally satisfactory if the stop has been well voiced (but the point is that the first satisfactory note above middle C should be selected as the model.) He will now get every note in this octave uniform in power, making sure that such adjustments as are required to this end do not change the characteristic tone-quality of any pipe so treated. If there are any pipes not speaking properly, these must be corrected before the regulation for uniform strength is begun. In the process of regulating for uniform strength some finishers play up and down the scale slowly and deliberately, while others play quite rapid chromatic passages up and down. There is no hard and fast rule about this. Personally, I play rapid **short** passages (from say C to E and back) with the object of detecting "the culprit." The culprit may be a note which is either too prominent in that series of notes or else too modest. Here lies the significance of the "model note," for it is by this yardstick that I am able to gauge the deviation from standard in one direction or the other of any note or notes in the immediate vicinity. Having got my colleague inside to correct the faulty pipe, or pipes, within the five-note zone selected, I proceed to deal similarly with the five notes (D♯ to G). I then run through the eight notes C to G again and make sure that they are as uniform as possible. The advantage of playing rapid scales up and down lies in the fact that it enables one to visualise mentally a horizontal straight line of tone, similar to the straight line formed by the natural keys of the manual on which one is playing. These very keys have been regulated to a uniform level by rubbing the fingers along their surfaces and correcting any irregularities felt by the finger. Substitute sounds for keys and the mind for the finger-touch, and the process of regulating the notes of a stop will, perhaps, be better grasped by the reader. I see in my mind the excrescences and the dips in the tonal line as my fingers traverse the keys, and I reduce the excrescences and fill up the dips until that line is smooth and level to my "brain-touch." One of the finest regulators and finishers I ever met was the late Henry S. Vincent of Sunderland: I have watched him many a time running his fingers rapidly over a succession of notes and picking out the "culprits" with unerring accuracy and bringing them into line with an equally unerring judgment. He liked to close his eyes during the operation or, better still, work in semi-darkness if possible, so that he could concentrate on the tone-line more effectually. When he had finished a stop, it **was** finished—it was a "midsummer night's dream." To continue my exposition of regulating the middle octave, it is a simple matter to fit G sharp to treble C into the tonal line and to proceed with the upper octaves in similar manner. When the stop has been regulated from middle C to top, the tenor octave can be tackled, the notes being played up and down rather more slowly at first to allow for the tendency of these larger pipes to speak less promptly. I refer, of course, to the unison rank: octave ranks are treated accordingly, the lowest octave being regulated after the same manner. The 8 ft. octave is tested note by note with due reference to the tenor octave so as to ensure continuity of power. Since the basses of many stops are not exactly the same in quality as the upper portion, the finisher has, as a rule, to secure the necessary uniformity of strength and quality in this lowest octave, treating it as a separate register.

After the complete stop has been regulated, it is a good plan to test the upper octaves from treble C by playing chords up and down and noting the effect of the top note of each chord. These upper notes tend to **appear** weak to the human ear since they are "masked" by the lower notes of the chord. A useful chord for this test is that which consists of treble C, middle C, tenor G, and tenor E (the lowest note), namely, the chord of the sixth or first inversion of the common chord of C major. If this chord is played in succession semi-tonally from treble C (top note of chord) to say C in alt, the finisher can easily detect any weakness occurring at the top note and have that pipe made louder till the balance is restored. After completing this operation it is advisable to add middle G to the above-mentioned chord (tenor E, tenor G, middle C, middle G, treble C), and repeat the progression of chords with careful observation of the effect. In regulating the dulciana and stops of this class, the above method is extremely useful.

Reeds may be regulated in the same manner as flue stops, but it is advisable to pass from note to note more slowly at first and then to quicken the pace so as to get a general impression of the finished result.

A very difficult question arises in connection with the relationship between the pipes and the listener. It is well known that a stop (and at least certain pipes belonging to that stop), sounds differently to a listener standing close to the organ from what it does to a listener standing at a distance from the organ. **Is the finisher justified in assuming that what he is hearing at the console is a true presentation of the tonal properties of the instrument?** Many finishers would contend that it is. There are always the two rival viewpoints—that of the player and that of the listener in the building. If the console is detached and situated at a distance from the pipes, this question hardly arises, since the player is himself a distant listener. But if the console is "attached" and therefore close to the pipes, the finisher has to decide whether he will judge his effects from the console position or from a position selected in the main building. Doubtless he should do both, or at least ascertain the actual difference of effect between one and the other before arriving at a final decision. A mixture or a reed may sound too assertive and brilliant at the keys, yet may produce a well-balanced result at a respectable distance from the pipes. The **organist** will probably complain of the excessive brilliance of the mixture or the aggressive effect of the reed (or reeds), while the audience will be favourably impressed by the general tone of the organ. It is a difficult problem for the organ builder to solve to the satisfaction of all parties, and as a rule the organist has his way. Schulze and Father Willis were neither of them respecter of persons: both of them judged the effect of their organs from various parts of the auditorium and finished them accordingly. No doubt three-fourths of the difficulty will vanish with the almost universal adoption of the detached console, and the finisher of the future will not have to consider the rival claims of player and listener.

CHAPTER XI

Tuning

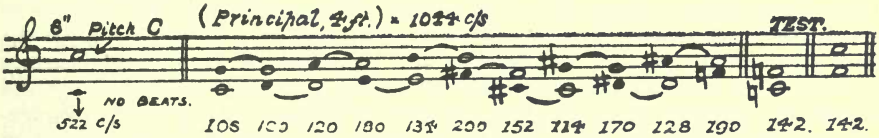
TUNERS are equipped for their job with a set of tuning cones of solid brass and a reed knife about 16 to 18 in. long. There are eight main methods of adjusting the pitch of organ pipes according to their structure and design: (1) increasing or reducing the diameter of the top of an open metal flue pipe by means of the tuning cones; the pointed end of the cone being inserted into the open top of the pipe to sharpen it, and the wide open end of the cone being cupped over the top of the pipe to flatten it: (2) tapping cylindrical slides or clips up or down to flatten or sharpen an open metal flue pipe: (3) opening or closing (partially, as a rule) a rectangular slot cut in the top of the tube of an open metal flue pipe: (4) turning a wooden slot-cover to left or right to cover or uncover the slot cut at the top of an open wood flue pipe: (5) pulling up or pushing down a thin metal shade or cap hinged to the top of an open wood flue pipe: (6) pulling up or pushing down a wooden stopper or tompion fitted in the top of a stopped wood or metal flue pipe: (7) tapping up or down the tuning spring (or wire) of a reed pipe: (8) opening or closing (partially) the slot cut in the top of a reed pipe resonator.

(1) is done with the tuning cones: (2) to (4) with the reed knife or a chisel: (5) and (6) are done with the tuner's fingers: (7) is done with the reed knife, and (8) with either the reed knife or a chisel.

Cone-tuning tends to injure the pipes in course of time, since it is necessary to use a certain degree of force with each stroke of the cone. Tin slides are far preferable, though if fitted to the smaller pipes (above 6 in. C, for instance) they are a nuisance, the pipe being too light to resist the **upward** stroke of the tapping knife so that it jumps out of its hole. Slotted pipes, if of metal, have tin slides fitted over the slot leaving a portion of the slot uncovered above the slide: if the metal pipes are large and tall (e.g. front pipes) they are tuned by the slot tongue: the same applies to large wood pipes, except that the slot opening is adjusted by means of a flat piece of wood or slot-cover. The stoppers of large stopped pipes (e.g. the pedal bourdon) are pulled upward by the hand to flatten the pitch and hammered down to sharpen. Reeds are usually tuned by the spring which adjusts the vibrating length of the tongue, especially as the springs are easily reached by the reed knife (or should be); but if violent changes of temperature occur during the year—and this does occur in buildings which are not heated during the winter months—the tuning of the tongues by means of the spring will make the reed more brilliant in tone in winter than in summer, since the tongues will be longer in relation to the length of the tubes after being tuned flat in cold weather, and shorter in relation to the tubes after being tuned sharp in hot weather. If the reed was originally regulated at a time when the temperature of the building was, say, 55 degrees Fahrenheit, the tongues would have been tuned to vibrate at the optimum length to match the length of the tubes: any alteration, therefore, in the temperature of the building above or below 55 degrees, especially if it exceeds five degrees either way, is bound to upset the balance between the tongue-length and the tube-length. It follows, therefore, that the tuner may have to adjust the slots at the top of the tubes as well as the tuning springs if the reed is to preserve its original power and quality. Many tuners regard this reasoning as so much "hair-splitting," and are of the opinion that tuning by the spring is quite sufficient at all seasons of the year; while on the other hand Messrs. Henry Willis and Sons insist on their own reeds (with the exception of the two top octaves of the 8 ft. stop and the corresponding octaves of the clarion) being tuned by the slot as a standard rule. Certain imitative reed stops are obviously best tuned by both the slot and the spring, since the resonators are very sensitive to changes of temperature; and in any case it is perfectly safe to say that all reed pipes are liable to automatic maladjustments from various causes over which the tuner has no control in the interval between his visits, so that if the reeds are tuned by the spring they must also be tested for tone and regulation and, if necessary, properly restored to their original status. I am, of course, assuming that the reed in question has been properly voiced in the beginning and that it is the duty of the tuner to see that it retains its original character and power as left by the finisher.

Laying the bearings is the *pons asinorum* of the novice tuner. All keyed instruments are now tuned to the "equal temperament," and have been so tuned in this country for the past hundred years in spite of great opposition on the part of many musicians in the early nineteenth century. J. S. Bach introduced this system two hundred years ago, and it was adopted on the continent long before we in this country could be induced to accept the change. The tempering of the intervals is certainly not conducive to sweetness and smoothness of chordal music, especially when the chords are sustained, and the organ suffers more from the dissonances thus produced than the piano or the harpsichord. It is therefore all the more necessary that the organ should be well tuned, and before all things it is necessary that the bearings should be properly laid.

The following scheme for laying the bearings in the middle octave of the principal, 4 ft. (the stop universally chosen for this honour) is the one I use myself. The "pitch-pipe" of the organ builder is the six-inch treble C pipe of the 4 ft. principal, sounding 1044 vibrations per second in accordance with the "New Philharmonic Pitch" (C=522 c/s.).



Assuming that treble C of the principal is of correct pitch to the tuning fork note, this treble C note is held with middle C, and middle C is tuned dead true, with no beats perceptible. Middle C and G above (a fifth) is next held and G is tuned first perfect to middle C (no beats), then slightly flattened till beats at the rate of 106 per minute are heard. Note that it is the tail-less crotchet that has to be tuned to beat with the semibreve in each case as indicated in the diagram. D is then tuned to G (a fourth), first perfect with no sign of a beat, then slightly flattened till beats are heard at the rate of 160 per minute. A is tuned to D (a fifth) first perfect, then slightly flat, beating at the rate of 120 per minute. E is tuned perfect to A, then flattened at the rate of 180 beats. B is tuned perfect to E, then flattened to beat 134 per minute. F sharp is tuned perfect to B and then flattened to beat 200 per minute. Middle C sharp is now held with the F sharp (a fourth above), tuned perfect and then made flat to beat at the rate of 152 per minute. G sharp is tuned to C sharp with no beats, then flattened to beat at 114. D sharp is tuned perfect to G sharp and flattened to beat at 170. A sharp is tuned perfect to D sharp, and flattened to beat at 128. F natural is tuned to A sharp perfect, and then flattened to beat at 190. F natural is now held with middle C, and this interval of a fourth should not need tuning, if the foregoing fifths and fourths have been correctly tempered. F natural held with treble C (a fifth) should also be correct, beating at the same rate as F and middle C, namely 142 per minute (or approximately at this rate). If these two test intervals are not right, and either too quick or too slow in the beats heard, F natural must be tuned to A sharp again, the beats being slowed down if the fourth F and C is too quick on test, or quickened if the interval F and C is too slow. The tuner must proceed to work back the reverse way, **sharpening** each note in turn till he gets to an interval that is beating at the correct rate. For example, let us suppose that the test interval middle C and F gives too quick a beat: then F with A sharp is held and F is slightly **sharpened** till this interval gives the required rate of beat. A sharp is next held with D sharp: if this interval gives too quick a beat, A sharp is made sharper till the beat is right. But if the interval A sharp and D sharp happens to be beating correctly, there is no need to continue, since the bearings are correctly laid and the middle octave is in tune. Should, however, the interval require further adjustment by sharpening the A sharp (as before stated), the next interval (G sharp with D sharp) must be held and re-tuned similarly, and so on all the way back till the initial error has been traced. It may be that the first interval (middle C with G above) was not quite correctly tempered, in which case the tuner will have gone the whole of the way back again to where he started—a by no means unknown event with beginners! If so he must pocket his pride and start afresh. In order to avoid such a contingency it is advisable to take the necessary pains to acquire the "beat-sense" by using a metronome. Set the metronome pendulum to beat at the required rate per minute and listen carefully to this beat for a few seconds: then stop the pendulum and, holding middle C with G, tune the G flat to C so that the beats correspond as closely as possible to the metronome beat. In order to facilitate matters it is a good plan to beat time with one's finger in imitation of the pendulum stroke and at the same frequency so as to impress the rate of beat on the mind. If possible, the technique of laying the bearings should be learnt at the voicing machine, since the tuner can hold his own notes and tune the pipes at the same time; whereas if he has to stand on the passage-board inside the organ in order to tune the pipes, he must have an assistant at the keys who may not be too appreciative of the delays and mistakes inseparable from the early efforts of an inexperienced hand. The above instructions, however, will, I hope, prove of service to the amateur who has succeeded in putting together a small organ in his own house and would like to be able to tune it himself without outside aid.

Since most organs are now tuned to the "New Philharmonic Pitch" which is 522 cycles per second at treble C (at 60 degrees Fahrenheit), I have given the beat-rates in harmony with this particular pitch, as marked in the diagram below each interval. As a matter of fact, the beats would not differ materially for a pitch of 528 cycles at treble C, or for one of 517. The important lesson that the tuner has to learn is how to temper each successive fourth and fifth so that their beats are in proper relation to one another. I believe it was the late Thomas Elliston, in his well-known book, "Organs and Tuning," who first pointed out the importance of tuning the fourths to a quicker beat than their adjacent fifths. A large number of tuners tune adjacent fourths and fifths to the same beat-rate, gradually increasing the speed of beat as each higher set of fourths and fifths is tuned. Thus, C G and D G are both tuned flat to the same degree of flatness (G being flat to C and D flat to G as they should be, **but** both intervals beating at the same rate): then D A and E A are tuned flat to a slightly quicker beat, but both beating at the same rate; and so on. I have in many cases completely failed to convince tuners that this is scientifically incorrect, but I believe that the majority of tuners to-day have been converted. Elliston was right, and he makes it clear in his book why he is right. It was from this same book that I gleaned in my youth the information I needed on the subject of fine tuning. The figures given below each interval in my scheme represent the correct ratios of the tempered beats and are based on mathematical calculation.

Should the bearings be laid on an 8 ft. stop, the above figures are divided by two: thus, 53, 80, 60, 90, 67, 100, 76, 57, 85, 64, 95; the test interval C F beating at 71. All soft stops of the dulciana and the echo string type should have their bearings laid in the middle octave and then the other notes above and below the middle octave tuned to the middle octave. And this is the next procedure with the tuning of the principal. The bearings being completed, the tuner now tunes treble C sharp to middle C sharp, treble D to middle D, treble D sharp to middle D sharp, and so on to the top note: then he tunes B below middle C (i.e. tenor B) to middle B (octave above), tenor A sharp to middle A sharp, tenor A to middle A, and so on till CC is reached. If the pipes are planted "every other note" on the soundboard, it is more convenient to tune every other note, C sharp, D sharp, F, G, A, B, etc., first, then D, E, F sharp, G sharp, A sharp, C, etc.; and likewise in the tenor and CC octaves. Since, however, the octave can be tuned to two alternative "commas" and the wrong comma may quite easily be chosen, it is advisable to test each of the notes that have been tuned in the lowest two octaves by holding the fourth above it and then the fifth above it to see whether both of these intervals are giving the correct beats. Thus, after tuning tenor B to middle B, try tenor B with E above (fourth) and see whether this interval beats at 134: then try tenor B with F sharp above (fifth) and see whether this beats at 100. It will be highly inconvenient to identify the exact pulsation for each fourth and fifth so tested all the way to CC: it is therefore sufficient if the **relative** speeds of each pulsation are noted, so that the fourth and the fifth both beat in ratio to one another and neither too quick nor too slow. At the same time the octaves must always be tested so as to keep them true. The upper octaves may be similarly tested in fourths and fifths, but tuners rarely do so. I strongly advise the beginner to test every fifth from middle F sharp with treble C sharp and upwards to the top of the keyboard in order to make sure that there are no fifths beating too rapidly. Obviously, every interval increases the speed of its beat as the pitch of each note is raised: thus, treble F sharp with the C sharp above will beat at twice the rate of middle F sharp with treble C sharp. One must, therefore, only look out for intervals that may be too dissonant to be tolerated and correct them. Whatever correction is given to a note in relation to its fourth or fifth (above or below) care must be taken to keep the octave above and below dead true. If by any chance the body of a pipe is touched with the hand it must be left to cool before being finally tuned.

All stops, with the exception of the dulciana, and other soft stops not belonging to the flute category, may be tuned to the principal. Some tuners start at the top note and work down: others always start at middle C and work up, then tune the tenor B and down.

Mixture ranks are tuned to the principal one at a time, the other ranks being damped either by plugging the tops of the pipes with wads of cotton wool or by slipping small bits of paper in their mouths. It is customary to tune all mutation ranks perfect. It must be pointed out, however, that very rarely can it be said that a mixture of three or more ranks supplied by a common pallet per note remains dead in tune when other stops are drawn with it unless special arrangements have been made by the builder to safeguard the wind supply against "robbing" or variable pressure. One—though not the only—reason why Mr. Compton's mixtures are so successful is that each rank is independently supplied with wind and there is "no robbing of Peter to pay Paul." The Willis reservoir compensator device also plays an important part in supplying constant pressure to every rank of pipes in the organ.

Flute stops must never be tuned to the principal alone: a third stop should be added, such as a small diapason or a viol. The 4 ft. flute is well known to present difficulties owing to its tendency to "draw" and pretend to be in tune when it is not. It should be tuned to the principal and an 8 ft. flute or a viol. 2 ft. flutes should be tuned to the principal and a soft 8 ft. flute. Reeds are tuned to the principal, but the bottom octave of the 8 ft. reed, and the two lowest octaves of the 16 ft. reed, are tuned to the octave above without the principal being drawn. Some tuners tune the 16 ft. reed and the 4 ft. reed to the 8 ft. reed, especially if the principal is too soft to be properly heard against a powerful chorus reed. It is often more convenient to tune a powerful 8 ft. reed to the principal **and** large open diapason from middle C to treble C only, then to finish the tuning with octaves up and down from treble C sharp to top and tenor B to bottom respectively.

Pedal pipes are tuned to the principal as a rule; but all depends on circumstances and the relative positions of the stops, so that it may be more convenient to tune to the large open diapason. Pedal 16 ft. reeds are best tuned to the manual 8 ft. reed, and all pedal reeds other than the 16 ft. (e.g. the 32 ft., 8 ft. and 4 ft.) should be tuned to the 16 ft. reed. Manual stops duplexed on the pedal will, of course, have been tuned as such.

Care must be taken to see that the various divisions of the organ (great, swell, choir, etc.) are in tune with each other. This may be secured by getting their respective principals in tune, but if there is no principal (or its equivalent) in one or other of them, it will be necessary to lay bearings on a unison diapason or viola or whatever stop can be selected other than a flute or a reed as a tuning standard. Allowance must also be made for the slight rise of temperature caused by an electric lamp (or even a candle) placed in a swell box to enable the tuner to see the pipes, to say nothing of the heat of his body if he is standing on a centrally placed passage-board for half-an-hour or more. In any case, it is usual to set the pitch of an enclosed division slightly sharper than that of an unenclosed one in order to allow for a change of temperature after the tuning has been carried out.

TUNING

The tuning of the celeste has been expounded in Chapter III.

In conclusion, if an organ is to be kept in good tune it must be regularly and frequently tuned and not left for several months without attention. Organs in country churches are sadly neglected, and in numerous instances are expected to function gaily for twenty or thirty years without a single tuning. The very longest interval permissible between two consecutive visits from a skilled tuner is six months, and this is really too long even for an organ without reeds. A conscientious tuner will not be content with "knocking the reeds into tune," but will run through all the stops and correct any faults he may find. He should be allowed sufficient time by his employer to do his work properly, and owners of organs should be prepared to pay a reasonable fee for their maintenance.

CHAPTER XII

The Pipeless Organ

THE introduction of electronic sound systems since the first world war has made possible the invention of a new type of musical instrument capable of giving sustained tones in imitation of the Organ. Such an instrument can boast of a number of virtues which commend it to the clergy and others who find themselves unequal to the task of raising the necessary funds for acquiring the now very costly pipe organ. For, it has to be admitted, the electrotonic organ is obtainable at a price which, compared with that of the Organ, is extremely moderate. Furthermore, the new type of instrument occupies very little floor space and even less height—a consideration of vital importance to the incumbents of country churches which in the majority of cases seem to have been designed by architects who were not interested in the Organ of classic tradition, since they provided no room in which a respectable pipe organ could be conveniently accommodated. Other advantages offered by the electrotonic organ are that it requires no wind supply; it merely has to be plugged into the electric mains supply: it requires no periodic tuning: it is able to produce a very wide range of volume from **pianissimo** to **fortissimo** by the simple use of a lever pedal controlling a variable resistance. No wonder that such a catalogue of virtues should prove an almost irresistible attraction to prospective purchasers.

I do not propose to name the different makes of electrotonic organ which have been placed on the market since 1928. In this short chapter I shall mention the principal types of instrument and endeavour to explain in what respects they differ from the pipe organ.

It is necessary to point out that whatever system is employed for the generation of sound by electronic means, the initial sound is in every case amplified by a thermionic valve system and fed to a moving-coil loudspeaker (or bank of loudspeakers) which radiates the tone into the auditorium. The "initial sound" is not an audible sound: it is an electric current fluctuation. Various methods are employed by various types of instrument of setting up these electric current fluctuations at varying frequencies: these fluxes are passed to the grid of the first amplifying valve and further amplified by succeeding valves till they are sufficiently developed in amplitude to be fed to the speech coil of the loudspeaker. The loudspeaker diaphragm is set in oscillation by the electric currents driving it, and audible sound waves are thus produced in the building. One loudspeaker is obviously not sufficient for radiating the sounds, and there is no difficulty in employing a number of loudspeakers which can be placed in various parts of the building to enable every member of the audience to hear the sounds to equal advantage.

As far as I am aware, at the time of writing, there are five different systems of producing the initial current variations.

1. The electrostatic system: revolving discs with serrated edges make

periodic fluxes with the movable plate of an electrostatic condenser which produces the current variations at the required frequencies.

2. The electro-dynamic system: the same as the above, except that the discs energise with an electro-magnetic armature which varies the current flowing through a coil winding.

3. The valve oscillator system: the current fluctuations are produced by means of thermionic valves rendered "unstable" by the currents passing between their electrodes. These oscillations give complex harmonic waves and therefore do not require any form of synthesis for the production of various tone-qualities. Instead, unwanted harmonics are filtered out by means of suitable values of capacity and inductance. A very wide range of frequencies can be produced by means of a variable tuning condenser.

4. The photo-electric film system: the sounds are produced by means of (a) rotating scanning-discs inserted between a light source and a photo-electric cell, or (b) rotating wave-forms intercepting a light source and in turn modulating a photo-electric cell. Sound-track films can be artificially prepared so as to reproduce the actual wave-patterns of original tones. The frequency of the tone thus produced is determined by the number of slits in a circle cut in the rotating disc.

5. Air-blown reed system: the vibrations of the reed set up electrical impulses in a "tone-screw" which are fed to a valve amplifier. The reed motions vary the distance between it and the tone-screw, in turn varying the electrical energy and current output.

In the case of the first two systems the various tone-qualities have to be built up synthetically by reproducing as far as possible the harmonic content of the prototype. Thus, diapason tone would be copied by combining frequencies (which are pure fundamental tones) sounding 1, 8, 12, 15, 17, 19, 22 at least, with the appropriate strengths required (as indicated in Dr. Boner's charts). A flute tone would be much the easiest to reproduce, while a viol or a reed of the trumpet type would present serious difficulties in view of the big range of harmonics entailed. Provided that the system is not expected to succeed in reproducing every type of organ stop or orchestral instrument, it is capable of achieving a specialised result which entitles it to take its place in the hierarchy of musical instruments. This statement is equally applicable to all the five systems above enumerated, whether the tone-qualities are synthesised or produced from reeds or films. But I would emphasise the fact that the electrotonic organ is not the King of Instruments. The King of Instruments is essentially a "wind instrument," the sounds being initiated and developed by air under pressure and not by any other means. Other sound-producing systems may, of course, be introduced in the Organ—observe that I spell this word with a capital "O" when referring to the King of Instruments—such as the various percussion effects described in Chapter VIII, and even the electronic sound system itself (as, for example, on the pedal by way of saving the cost of large and space-taking pipes).* But none of these sound-producers are essential to the fundamental character of the Organ as a musical instrument existing in its own right.

Diapason tone, diapason choruses—chorus reed tone—these basic and characteristic tone-qualities and tonal effects cannot be reproduced by synthesis nor by any method of sound-production except that of the organ pipe. The distribution of sound from a large number of organ pipes occupying many square feet of space is far superior to that which must emanate from a loudspeaker diaphragm or from a number of such diaphragms even if they are distributed in different parts of the auditorium. The formant frequencies—whole bands of them, be it noted—engendered by the air waves in combination with the vibrating material of every organ pipe that speaks create a personality which constitutes the peculiar charm of a well-voiced stop or combination of stops.

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* It should be mentioned that free reeds (employed under pressure in the French reed organ and under suction in the American reed organ) are "wind-produced" and therefore admissible as such in a pipe organ. Since, however, they do not vary in pitch with changes of temperature as do organ pipes, they are under a distinct disadvantage in an organ except, possibly, on the pedal in the form of 16 ft. or 32 ft. reed tone. The same disadvantage applies to the diaphone which, too, is only really admissible as a producer of the lower tones.

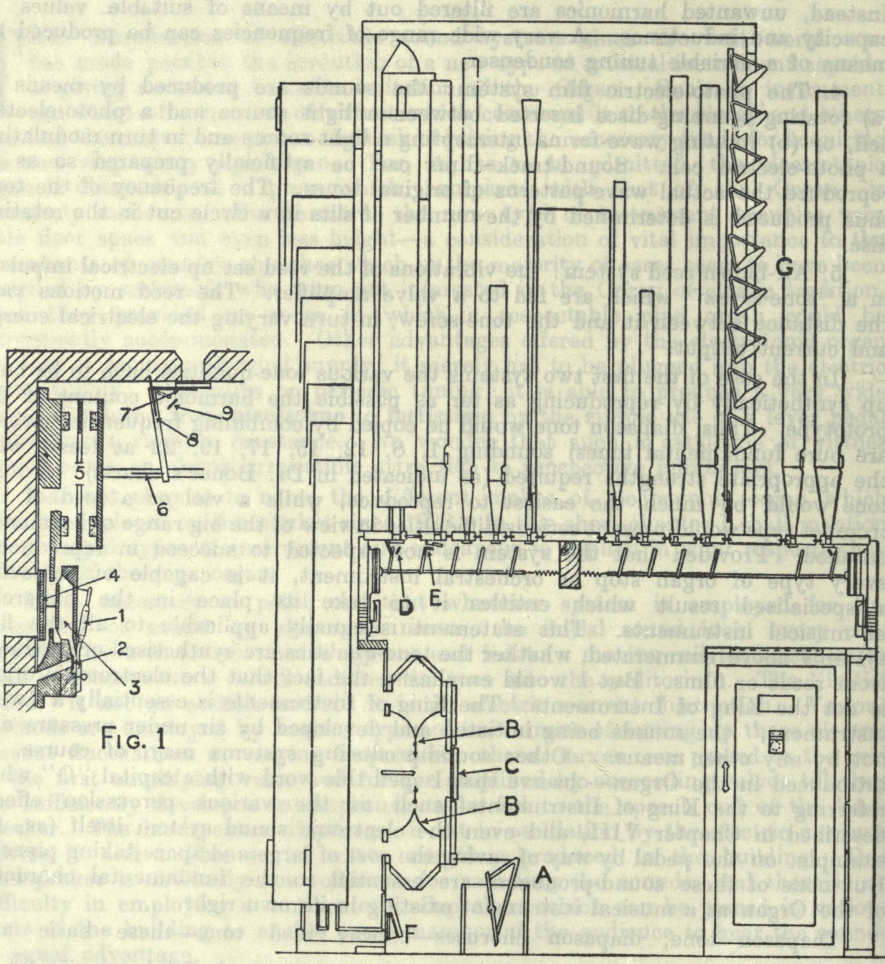


FIG. 1

FIG. 2

AUSTIN UNIVERSAL WINDCHEST PLATE IX

My friend, Dr. W. L. Sumner, a physicist of distinction, has expressed the matter with commendable succinctness in a letter to me. "As regards synthesising a sound," he writes, "it seems to me to be very similar to an attempt to synthesise vintage wine by the use of water, alcohol, traces of aldehydes, esters, colouring matter and sugar, etc. The real thing is vital and has a living character—the other is in comparison a corpse." This is not to say that the electrotonic sound producer is incapable of providing musical results: even the much needed formants may be introduced, as in the Trautonium. The point I would make is that the musical result produced by a collection of organ pipes artistically voiced and finished is absolutely unique in the world of sound, a fact that is not sufficiently recognised in these days of canned music.

Under the pressure of economic and financial considerations it may be justifiable to incorporate one or other of the electrotonic systems in the King of Instruments. 32 ft. and 16 ft. pedal tones are easily produced by this means and need no costly swell boxes to render them expressive and capable of a wide range of variable power. They would, of course, not vary their pitch with changing temperature as organ pipes do, and it may be objected that flue stops, in particular, would make bad partners with such sound-producers; but the discrepancy in pitch would not be so noticeable in these very low-toned registers as to provoke serious criticism, and the same objection could be raised against similar tones produced by the diaphonic method.

To sum up the matter: the all-electrotonic organ is undoubtedly a musical instrument and is capable of further development on its own distinctive lines. It is definitely not the King of Instruments and never will be for the reasons stated above.

CHAPTER XIII

Console and Mechanism

THE Console is the organist's *peculium*. Here he sits—conductor, controller, dictator, king, artist—call him what you will: the pipes become his slaves and the mechanism conveys his bidding. Here he sits, the monarch of all he surveys as his glance encompasses the rows of keys, the drawstops, the tablets, the pistons, the music-desk, and his feet make unerring contact with pedal keys, pistons, rocking levers. While all types of console are basically the same in design and lay-out, they differ in detail and in the number of controls supplied by the builder. I give photographs of six different consoles of modern design which the makers and photographers have graciously allowed me to reproduce. They all contain thumb pistons placed between the manual keyboards: five of them have four manuals and a pedalboard: one has five manuals: two of them have drawstop knobs to control the pipe-work, and four have stop-keys or tablets for this purpose. Five of them have pedal pistons, one has none of these; all have swell pedals.

Let us, however, examine the various features of the console in turn.

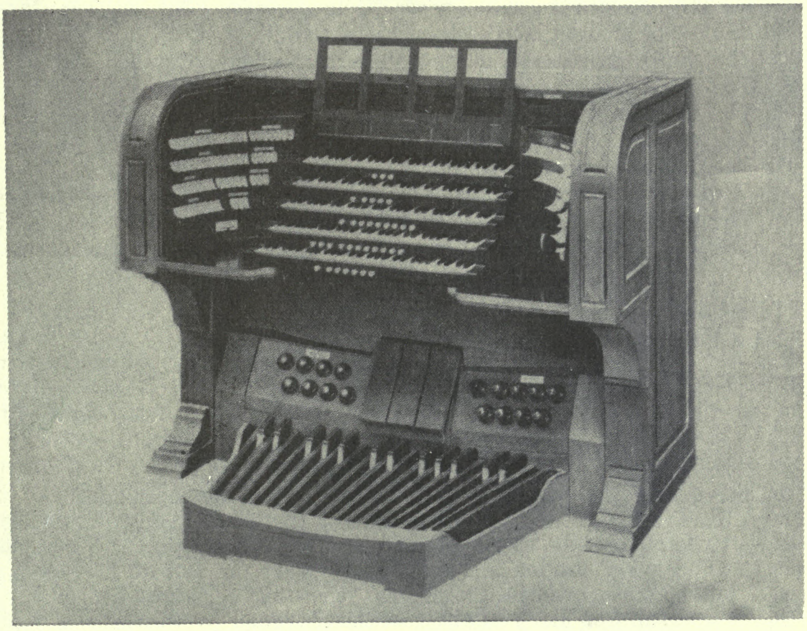
1. The **keyboards** or **claviers.** The conventional names of these are (counting from lowest to highest):—1. Choir;
2. Great;
3. Swell;
4. Solo;
5. Echo or Celestial.

To the above manual keyboards played by the hands we have to add the pedal played by the feet.

A few Continental organs have two pedalboards, but the modern organist appears to be quite content with one, especially as he is now being entrusted with a row of swell pedals (see, for instance, the Moller console of the organ in the Washington D.C. Auditorium), and he has only two legs! On the Continent the great is usually the lowest manual.

The compass of the manuals is CC to C^4, namely five octaves or 61 notes: that of the pedalboard is CCC to G, 32 notes. Many of the older organs possess a somewhat shorter compass for both manuals and pedals, stopping at F, G or A (54, 56, 58 notes) on the manuals, and at F (30 notes) on the pedal. The modern complete compass is necessary for the rendering of certain compositions, although a great deal of music written for the Organ can be played on the shorter compass. The prevalence of octave couplers has also made the five-octave manual advisable in order to complete the octave effect in the top portion of the compass. There are altogether eight C notes in the accepted nomenclature of pitch-frequencies: they are:—

CCCC - 32 ft.
CCC - 16 ft.



CONSOLE OF DONCASTER PARISH CHURCH

CC - 8 ft.
Tenor C - 4 ft.
Middle C - 2 ft. (or C^1)
Treble C - 1 ft. (or C^2)
C in alt - 6 in. (or C^3)
Top C - 3 in. (or C^4)

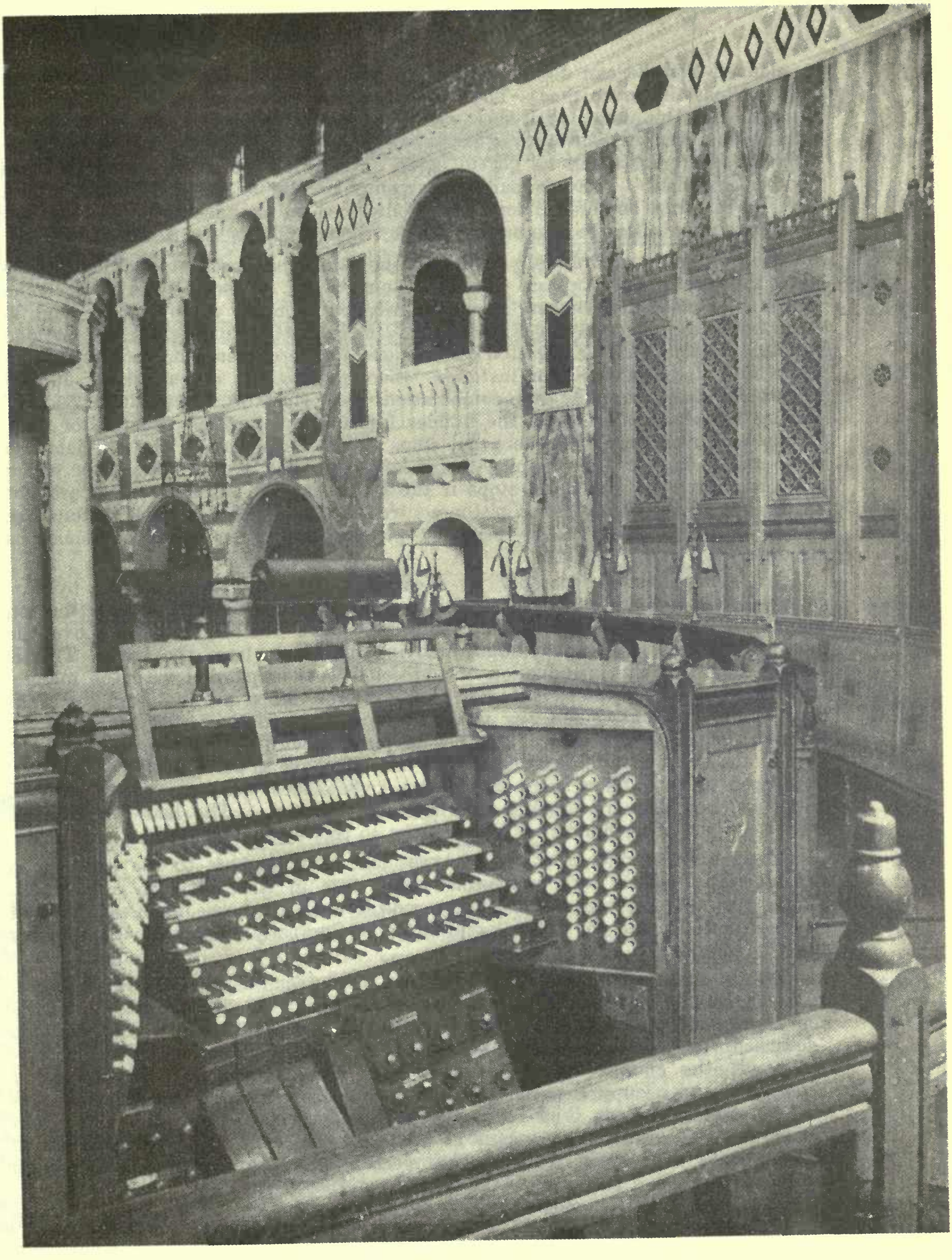
The following are the most generally accepted measurements for the console keys and fittings:—

MANUALS.

Length of natural (white) keys: 5½ in.; width, ⅞ in.
Length of sharp (black) keys: 3½ in.; width ⅜ in.
The sharps are raised ½ in. above the level of the naturals.
The distance between two consecutive sharps, 11/16 in.
The total length of the manual is 2 ft. 9½ in. (for 61 notes).
The overlap of two adjacent manuals is about 1½ in.
The distance between the manuals is about 2¼ to 2½ in.
If more than three manuals are provided they should be "inclined."
The depth of manual key-touch is 5/16 in. to ⅜ in.
The key should offer a "top resistance" of 4 to 4½ oz. for the first ⅛ inch, then 2 oz. for the last ¼ inch.

PEDALS. A concave and radiating pedalboard is now the universal standard, with a compass of CCC to G, 32 notes. The placing of the board should be such that the DD pedal key is exactly under the middle D of the manuals. The distance from the top of the middle natural key of the bottom manual to the top of the middle natural key of the pedals is 2 ft. 6½ in. The height of the sharps above the level of the naturals is 1¼ in.: the distance from centre to centre of the adjacent naturals is 2½ in. (though this varies slightly with different boards).

There are three types of stop-control which one may find on a console, according to the custom adopted by this or that builder. (1) The time-honoured **drawstop knob**; (2) the **stop-key** or rocking tablet; and (3) the illuminated piston-head, which when pushed in lights up (showing the stop to be "on") and when again pushed extinguishes the pilot light (showing the stop to be "off"). The third type is a feature of many of the consoles designed by the John Compton Organ Company. The first and second types are often employed on the same console, as the photographs show, but the tablets or stop-keys are invariably chosen for the cinema organ and for many concert-hall organs. Mr. Willis prefers drawstops for the speaking stops and uses tilting tablets for the couplers (as shown in the photograph of the Westminster Cathedral console). Drawstops are usually arranged on angle-jambs placed to the right and left of the player, while stop-keys may be similarly arranged (as in the Moller console at the Washington D.C. Auditorium) or "horse-shoed" as illustrated in the Compton console at the Bournemouth Pavilion. Many players prefer the stop-key inasmuch as it requires so small a movement, and, of course, a player is always in a great hurry to make his stop changes. On the other hand, the well-arranged drawstop jamb presents a handsome picture, and it is easier to take in at a glance the stop-list, especially when the tonal divisions are grouped together in separate sectional areas on each jamb, as shown in the Willis and the Harrison consoles. Lynnwood Farnam used to say that he was equally at home with either system, given a reasonable lay-out. It is hardly necessary to state that what every organist desires is a console



CONSOLE OF WESTMINSTER CATHEDRAL

so planned that he can do the things he wants to do with the utmost speed and the least inconvenience. There is apparently no one and only arrangement that satisfies this demand: if there were, we should not hear so many conflicting voices trumpeting their views on the subject. Standardisation is certainly desirable if organists can be got to agree on details, but so far agreement has not been reached. The keyboards most emphatically ought to be standardised and the majority of our builders have conformed to an agreed pattern and set of measurements for the manual keyboards, though not for the pedalboard.

The grouping of drawstop knobs on the jambs has been standardised in so far as the great organ stops are placed on the right and the swell organ stops on the left, but the other divisions are not necessarily found on any one particular jamb in every organ console so arranged. Not that it really matters if the player is provided with a sufficient number of piston controls and a general crescendo pedal operating the whole of the stops. For instance, when all that the organist had supplied to him for controlling the stop-combinations was a set of "composition pedals" (taking the stops selected by the builder for each composition pedal in or out), it was very necessary that the pedal stops should be placed on the left jamb so as to enable him to draw them with his left hand; but it does not matter which jamb is chosen for the pedal stops if the latter can be arranged to be brought on (or taken in) by means of a piston control such as "pedal to great pistons" or "pedal to swell pistons," or even by pistons controlling pedal combinations separately.

In some consoles (notably by Messrs. J. C. Hele and Co. and by Mr. Rothwell) the stop-keys are placed between the manuals, instead of over the top manual or on jambs, the object being to enable the organist to move the levers while he is playing without removing his hands from the keys. This is a good idea, but the introduction of additional keys in parallel with the manual keys presents certain disadvantages. For example, when passing from the swell keys to the great keys one has to avoid fouling a stop-key stationed between the two manuals, especially if one has to play a chord or passage on the sharp keys of the lower manual; and again, the manuals have to be separated sufficiently from each other to allow space for the stop-keys. These are not my own personal criticisms, but those of organists of my acquaintance. The late Sir Walford Davies, on the other hand, was very partial to this arrangement.

Many builders offer a choice of types and arrangements to the organist to suit individual tastes: this is especially the case in America. Messrs. M. P. Moller, for instance, whose all-stop-key console is shown here, make six different types of console; and the John Compton Organ Company make both the stop-key and the illuminated stop-knob type.

The console may be either built into the main organ as part of the structure, in which case it is given the title of "attached," or it may be separated from the main organ and placed at any convenient spot in the building, in which case it is "detached." Modern electric action has greatly simplified the mechanical lay-out inside the console, with the result that it can be made to quite small dimensions and occupy the minimum of floor space. One of the disadvantages of the detached console used to be the necessity of conveying wind to it from the blower and reservoir by means of long trunking; but it is now possible to dispense with wind entirely and employ electric current for all the working parts inside the console. This is the "all-electric console."

1. Let us first, however, turn our attention to the all-tracker console and the

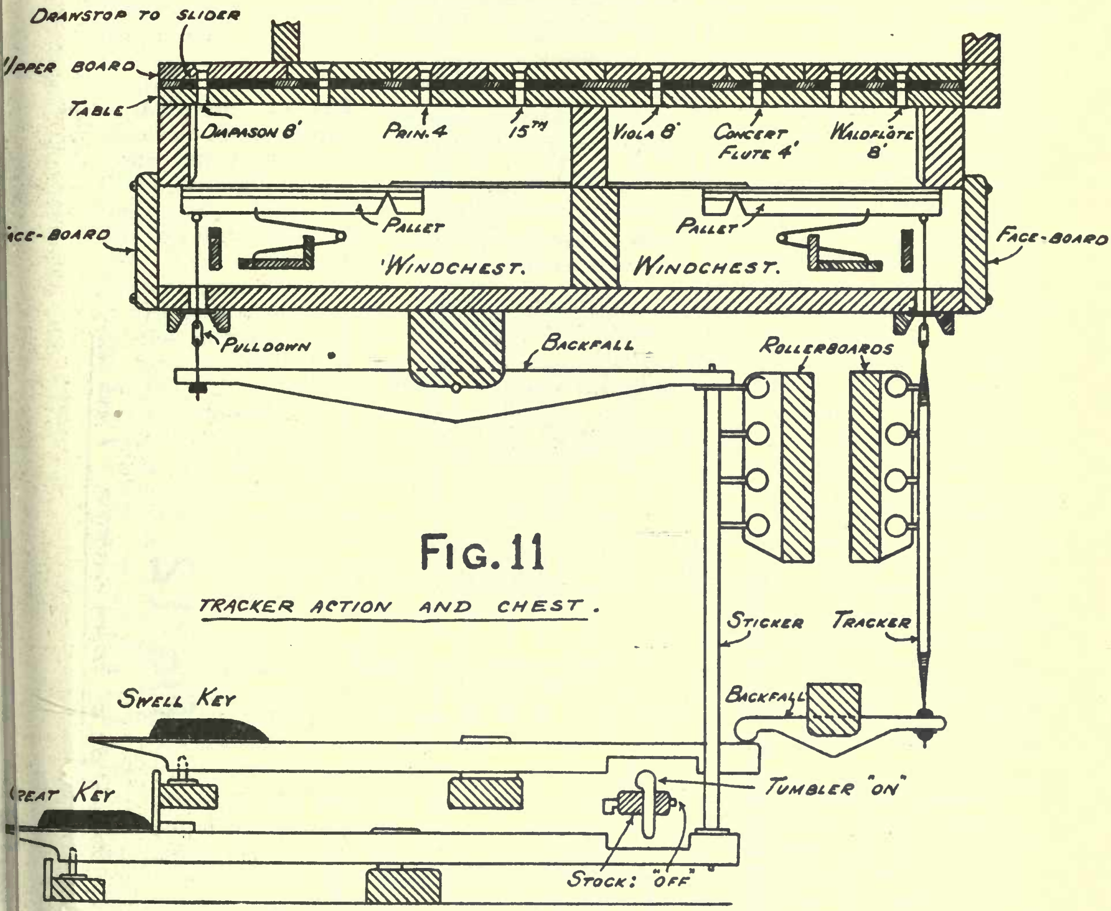

DRAWSTOP TO SLIDER
PPER BOARD
TABLE
DIAPASON 8'
PRIN. 4
15TH
VIOLA 8'
CONCERT FLUTE 4'
WALDFLÖTE 8'
ACE-BOARD
FACE-BOARD
PALLET
PALLET
WINDCHEST.
WINDCHEST.
PULLDOWN
BACKFALL
ROLLERBOARDS
STICKER
TRACKER
BACKFALL
SWELL KEY
REAT KEY
TUMBLER "ON"
STOCK: "OFF"

FIG. 11

TRACKER ACTION AND CHEST.

mechanism that connects it to the main organ. This was almost invariably attached to the main structure for obvious reasons, though there were examples of detached consoles situated a few feet away from the organ. The key mechanism was directly connected to the soundboards by means of (a) stickers, (b) backfalls, (c) pulldowns, (d) trackers and (e) rollerboards: these parts are all illustrated in Fig. 11, showing the arrangement for a two-manual chamber organ with two soundboards holding four stops apiece. The drawstop action is not shown, but the black lines between the "table" and the "upperboard" of the soundboard indicate the "sliders" which stop or unstop the wind from entering the pipe-feet from the "windchest" (which is filled with pressure-wind from the bellows). These sliders are worked to and fro by the stop-knobs at the console, being connected by means of (a) trace-rods, (b) rollers and (c) trundles, as shown in Fig. 12, (1) and (2). The manuals may be "coupled" (so that when the lower manual key is depressed the upper manual corresponding key goes down at the same time) by means of the "tumbler coupler," which is shown in Fig. 11.

DRAWSTOP ACTIONS

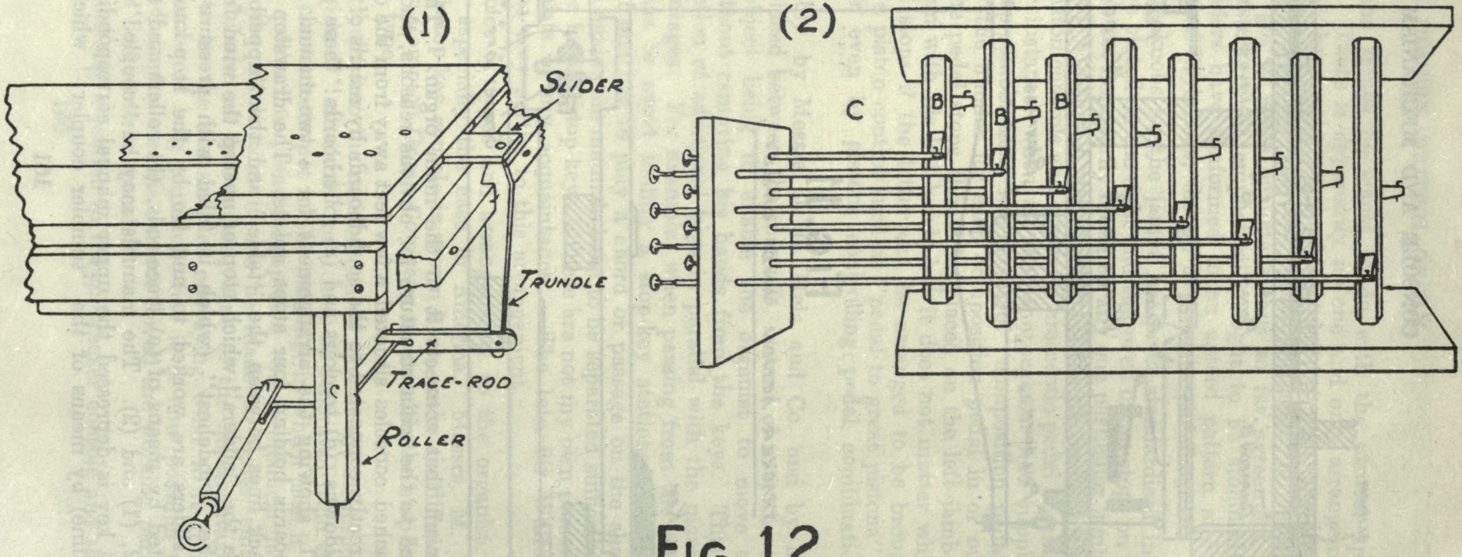
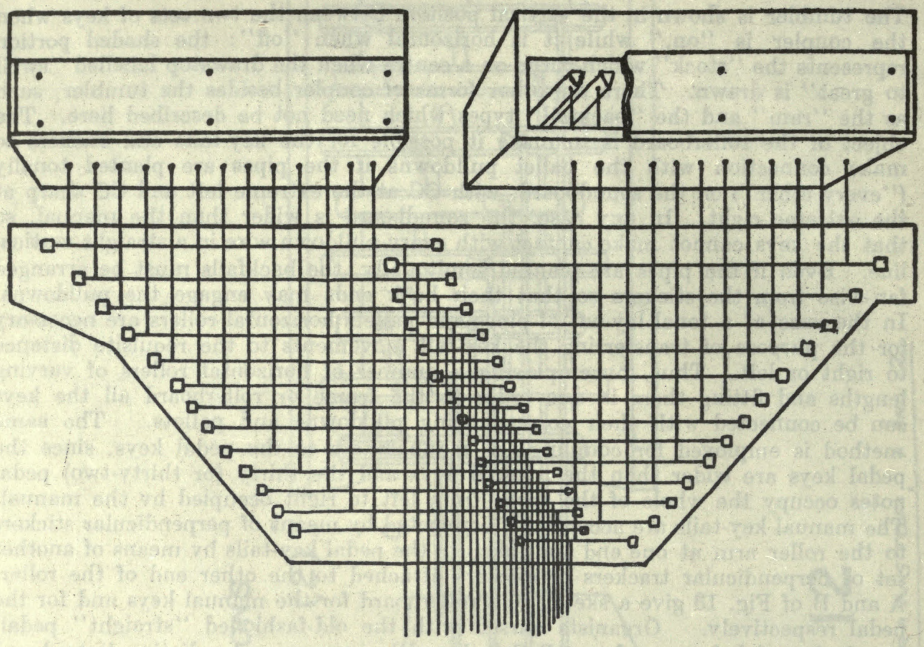

(1)
SLIDER
TRUNDLE
TRACE-ROD
ROLLER
C
(2)
C
B
B
B

FIG. 12

TRUNDLE DRAWSTOP, 1 AND 2.

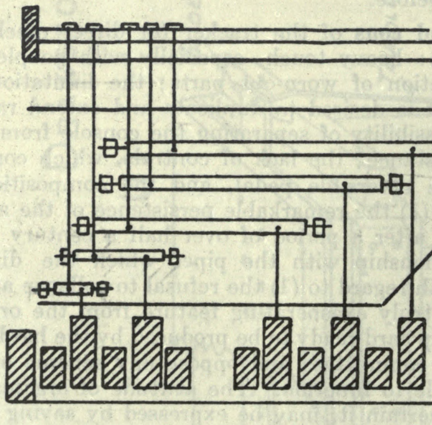
The tumbler is shown in the vertical position between the two sets of keys when the coupler is "on," while it is horizontal when "off": the shaded portion represents the "stock" which turns on a centre when the drawstop labelled "swell to great" is drawn. There are other forms of coupler besides the tumbler, such as the "ram" and the "backfall" types which need not be described here. The object of the rollerboard is to make it possible for the key-tails and stickers to make connection with the pallet pulldowns if the pipes are planted tonally ("every other") on the soundboard, with CC at the extreme left and CC sharp at the extreme right. In any case, the soundboard is wider than the manual, so that the keys cannot make contact with every pulldown wire in a straight vertical line. Even if the pipes are planted semitonally, the backfalls must be arranged fan-wise from the stickers so that their back ends may engage the pulldowns. In the case of a tonal lay-out of pipes and pallets horizontal rollers are necessary for the purpose of transferring the key-tail movements to the requisite distance to right or left. Thus, by employing a number of horizontal rollers of varying lengths and fitting them in due order to the frame or rollerboard all the keys can be connected with their corresponding pulldowns and pallets. The same method is employed for coupling the manual keys to the pedal keys, since the pedal keys are wider than the manual keys and the thirty (or thirty-two) pedal notes occupy the whole of the space from left to right occupied by the manual. The manual key-tails are accordingly connected by means of perpendicular stickers to the roller arm at one end and taken to the pedal key-tails by means of another set of perpendicular trackers or stickers attached to the other end of the roller. A and B of Fig. 13 give a sketch of a rollerboard for the manual keys and for the pedal respectively. Organists cursed with the old-fashioned "straight" pedalboard often sigh for a modern "R.C.O. board"—concave and radiating (introduced by Samuel Sebastian Wesley and Henry Willis I in collaboration). The change-over usually means a new rollerboard, since the radiating keys occupy different positions in relation to the manual keys from those of the straight board, and it is always well to bear this point in mind. One cannot simply change the boards and connect up as before.

What are the **pros** and **cons** of the tracker (or direct mechanical) system? The objections are obvious: heavy touch, especially with couplers drawn; noisy key action due to the friction of worn-out parts; the limitations of the direct mechanical system when it is desired to duplicate and extend ranks of pipes for multiple service; the impossibility of separating the console from the main organ except for a very short distance; the lack of controls, which consist only of the swell pedal, the horseshoe reversible pedal, and the composition pedals. The advantages are said to be (1) the remarkable persistence of the action in refusing to break down completely after a period of over half a century of constant use; and (2) the intimate relationship with the pipes which the direct mechanism creates for the player. With regard to (1) the refusal to collapse and make way for a modernised system is a truly exasperating feature from the organist's point of view, but a veritable trump card ready to be produced by the hard-headed business men who serve on church committees and oppose any scheme of re-construction so long as the organ is able to function. The attitude of organists to (2), as far as I have been able to ascertain it, may be expressed by saying that they regret the loss of this intimacy which has never been replaced since the introduction of pneumatic and electric action. The tracker touch can be reproduced in the modern organ but not the "touch on the pallet." It is, I think, generally agreed that a one-manual organ containing a set of lightly winded flue pipes should



ROLLER BOARD.

FIG. 13A



PEDAL ROLLER BOARD

FIG. 13B

be fitted with tracker key action in preference to any other, there being no couplers to upset the touch and no complications demanding pneumatic or electric assistance. If pedals are added, the action may be tracker, pneumatic or electric, as desired: it matters little which. One little point of difference between tracker and all other systems is the fact that the pallet is opened directly by the player's finger in the case of direct mechanical connection while it is very suddenly and smartly opened by the pallet-motor (or the magnet in the case of direct electric action) in all modern systems. Whether any advantage is derived from the old-fashioned direct control of the pallet is a question that has never been decided: I can remember organists in my boyhood days claiming a very distinct advantage for it, stating that the pipes could only speak at their best if the wind from the soundboard was admitted gradually and variably by the key. It was felt that the individuality of touch which distinguished this player from that was irreparably lost with the disappearance of the tracker key action. I am inclined to believe

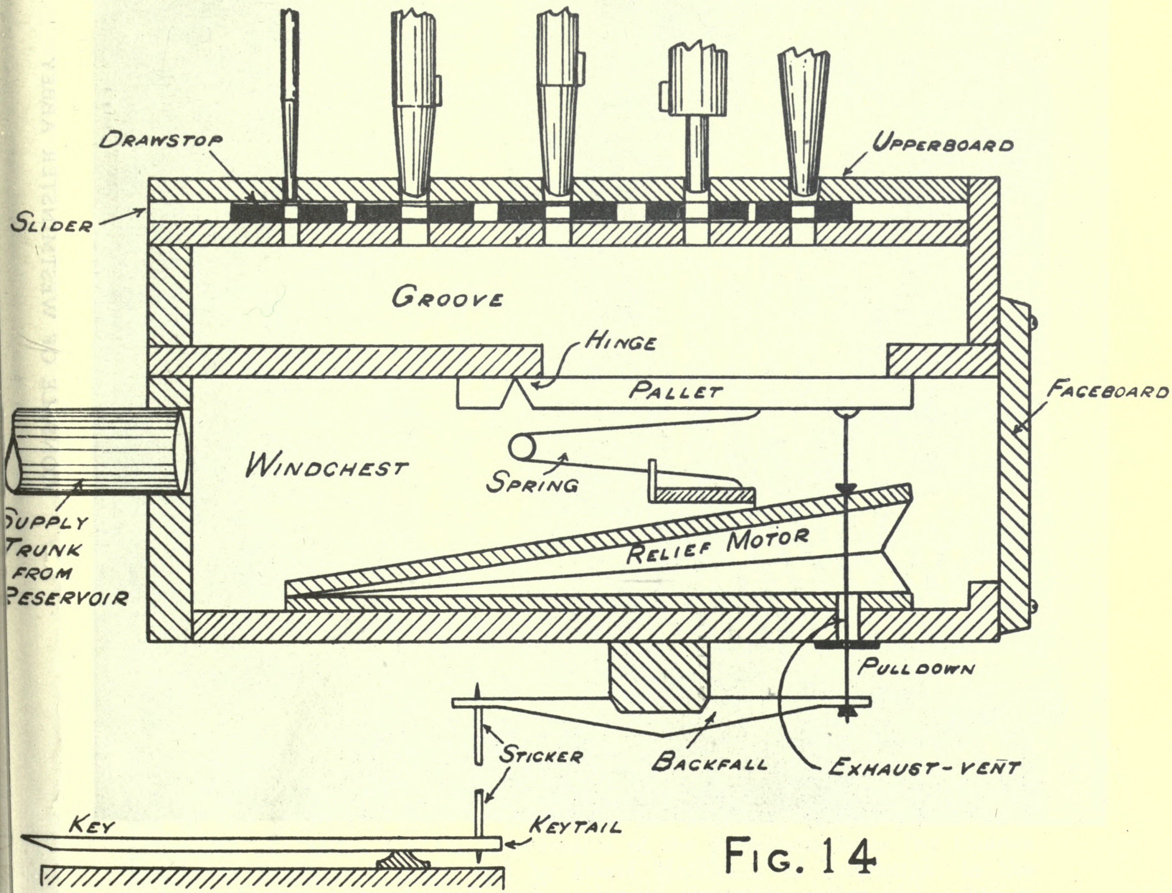
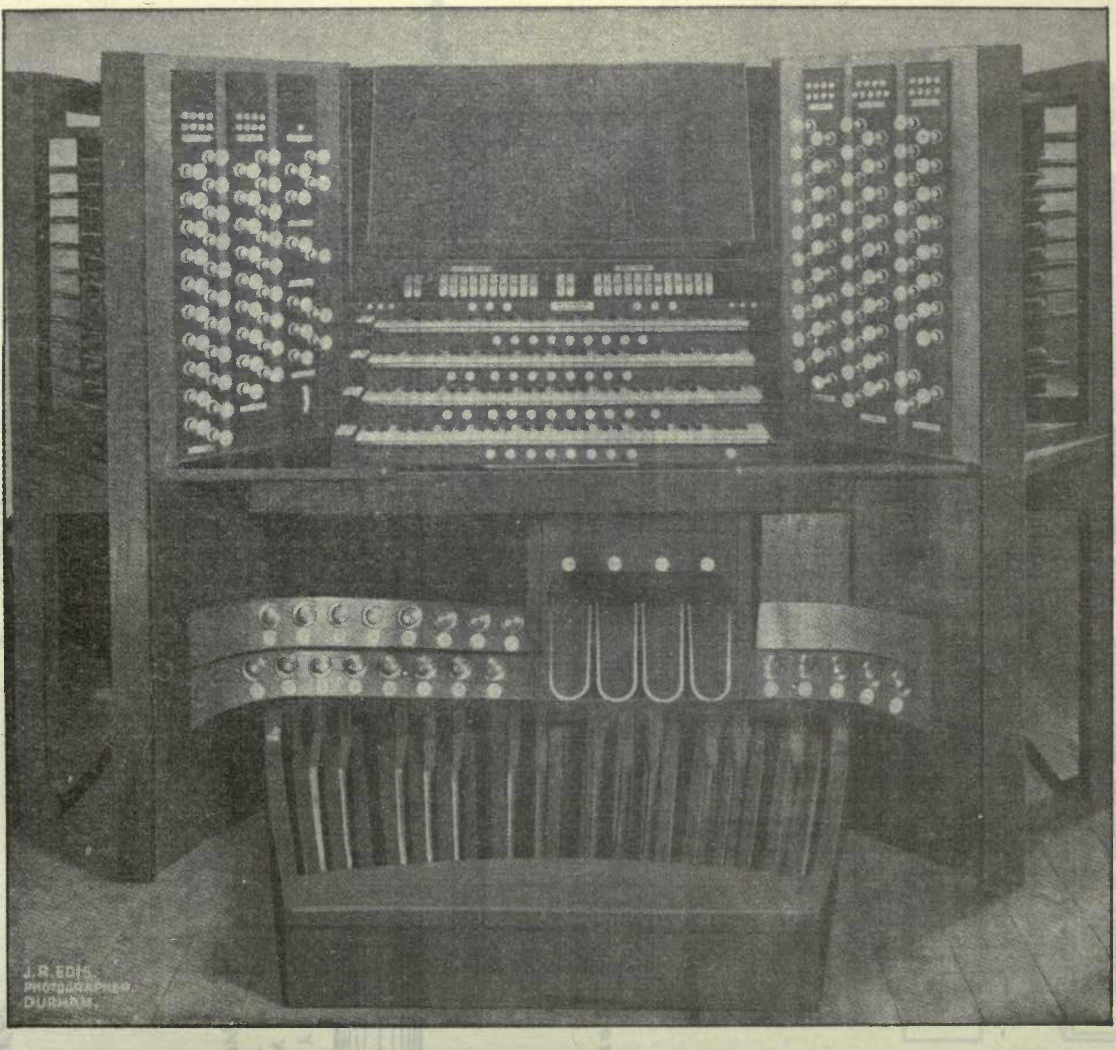

DRAWSTOP
UPPERBOARD
SLIDER
GROOVE
HINGE
PALLET
FACEBOARD
WINDCHEST
SPRING
SUPPLY
TRUNK
FROM
RESERVOIR
RELIEF MOTOR
PULLDOWN
STICKER
BACKFALL
EXHAUST-VENT
KEY
KEYTAIL

FIG. 14

RELIEF - MOTOR PALLET CHEST.


J. R. EDIS
PHOTOGRAPHER
DURHAM

CONSOLE OF WESTMINSTER ABBEY

that there is a modicum of truth in this contention, though it can be pressed too far. Individuality of touch is still possible with electro-pneumatic action, though it seems to be of a different kind. This fact was demonstrated in the most interesting manner at the re-opening of the organ in the Royal Albert Hall after its rebuild by Messrs. Harrison and Harrison. Three organists—Sir Walter Alcock, Dr. G. Thalben-Ball and Dr. G. D. Cunningham—played their respective pieces in succession, each one displaying his consummate skill and artistry in his own style, and each **producing subtle differences of quality from the same stops.** At a series of organ recitals given at Westminster Cathedral some twenty years ago one had the opportunity of hearing many of the world's finest performers. They differed enormously and each produced effects peculiar to his style and manipulation of the keys. Of these there was one who created real magic from the great diapasons, making them sound as none of the others had done. That man was Sir Walter Alcock. Individuality of touch was in this particular case a paramount feature. Each recitalist displayed outstanding gifts of interpretation and expression, produced his own special effects and tonal combinations. The console was the original attached one fitted with tubular-pneumatic action of the very best design.

For the organ of to-day tracker action is hopelessly inadequate. Players insist on light touch, and all the modern controls. Detached consoles are the order of the day—the organist wants to hear his effects and not to have to guess what they sound like to the listener in the auditorium. Organ builders have not been slow to provide the needful. The lightening of the key touch and the introduction of coupling systems which did not involve any additional strain on the player's fingers was next made possible by means of pneumatic agency.

2. We come, therefore, to a consideration of the pneumatic console and its mechanism. The basic principle underlying all pneumatic systems is the inflating and exhausting of a small bellows so as to get a **movement** up and down or backwards and forwards. This small bellows is called a "motor" and can be made in various shapes and sizes. There are three main types: the hinged motor, which opens and closes like a reporter's note-book, and the circular, which resembles a pill-box in appearance and executes a parallel movement. There is also the "diaphragm" (called variably "purse," "pouch," membrane" by builders), which is a circular strip of leather mounted over a circular hole and fitted with a cap at its centre to take a connecting wire. (A diaphragm of larger dimensions and of rectangular shape is sometimes used for powerful movements.) All three will be found included in the various drawings illustrating pneumatic key and chest actions.

At first, the pneumatic motor seems to have occurred to builders as a means of relieving the heavy touch of a directly operated pallet: Fig. 14 shows how this was done. The relief motor **wants** to collapse by exhausting its mass of contained air through the opening or exhaust-vent (through which the pulldown wire is passed), but is held up by the pallet-spring. But as soon as the organist's finger presses down the key and pulls down the pallet, the motor starts exhausting and helps the pallet to overcome the inertia (due to suction) impeding its first movement. We shall see later how this relief motor was given a much more effective use in the pneumatic chest. Meanwhile the next step in the evolution of pneumatic key action was the introduction of the pneumatic lever (by Charles Spackman Barker, of Bath, and by David Hamilton, of Edinburgh, in the eighteen-thirties). This lever is really a hinged pneumatic motor with a lug or arm attached to its moving board as shown in Fig. 15, which gives an illustration

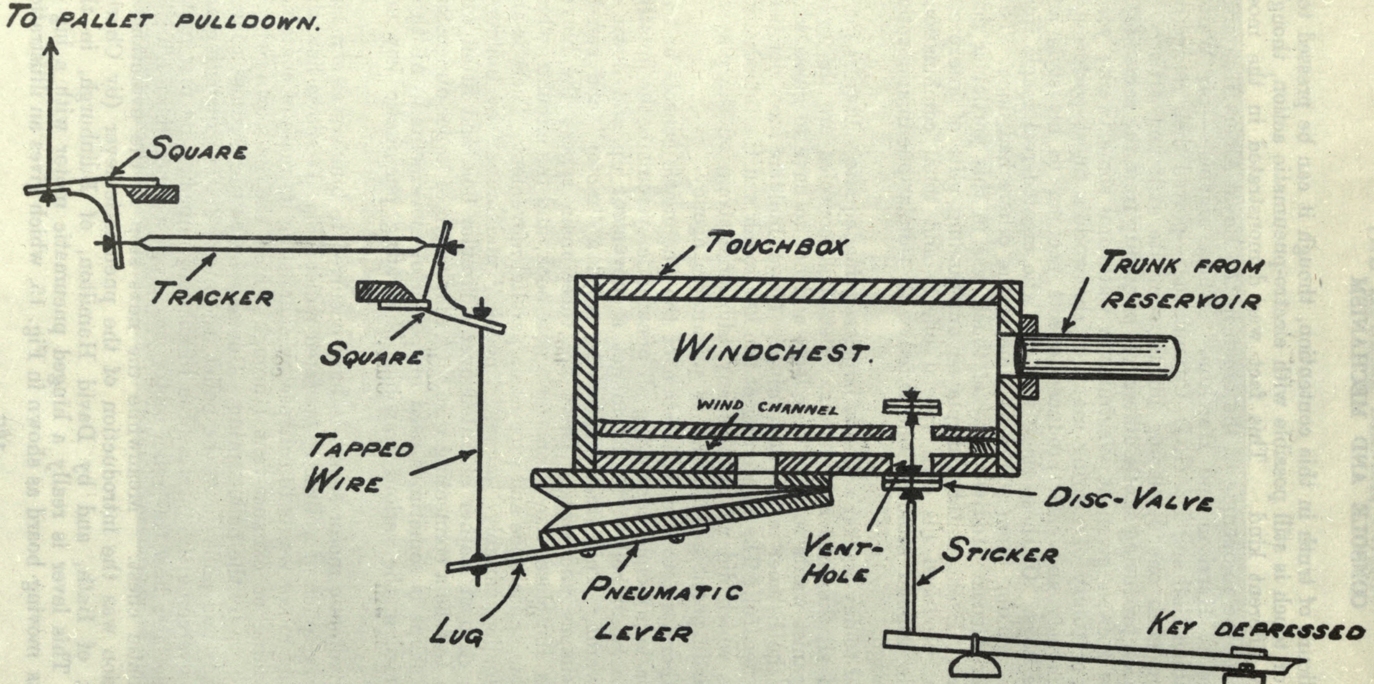

To pallet pulldown.
Square
Tracker
Square
Tapped Wire
Lug
Pneumatic Lever
Touchbox
Windchest.
Wind channel
Trunk from Reservoir
Disc-Valve
Vent-Hole
Sticker
Key depressed

Fig. 15

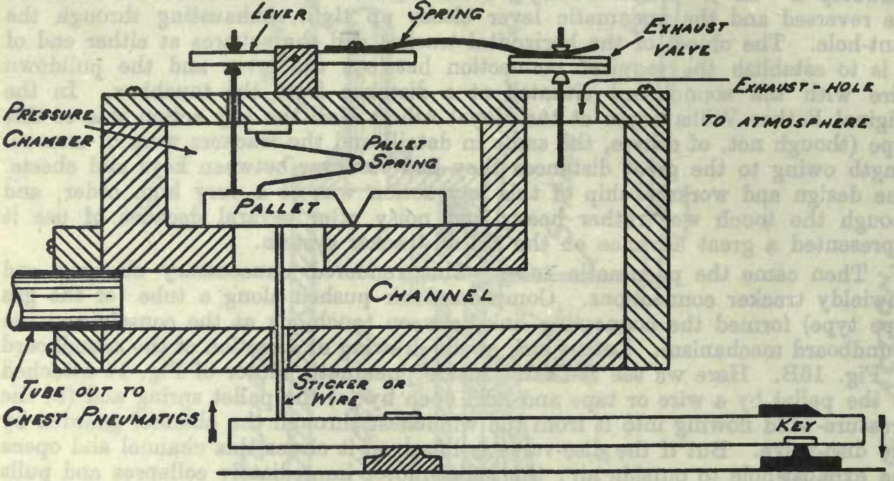
LEVER PNEUMATIC ACTION.

of one form of this action between key and soundboard pallet. Here the key is shown depressed; the disc-valve is pushed up and admits pressure-wind to the pneumatic motor-lever, which inflates and pulls down the tapped wire and square above, shifts the tracker to the right and the left hand square with it: the latter pulls down the wire attached to the pallet, and the pipe speaks (assuming that the drawstop is "on"). When the key is released, the whole of the above movements are reversed and the pneumatic lever closes up tight, exhausting through the vent-hole. The object of the horizontal tracker and the squares at either end of it is to establish the required connection between the lever and the pulldown wire with the soundboard situated at a distance from the touchbox. In the original Father Willis organ at the Royal Albert Hall the key action was of this type (though not, of course, the same in detail) and the trackers were of unusual length owing to the great distances they had to cover between keys and chests. The design and workmanship of this key action was of a very high order, and though the touch was rather heavy and noisy after several decades of use it represented a great advance on the old all-tracker system.

Then came the pneumatic **tube.** This rendered unnecessary all long and unwieldy tracker connections. Compressed air pushed along a tube (of the gas pipe type) formed the connecting link between touch-box at the console and the soundboard mechanism. Let us look at the drawing of a section of the soundboard in Fig. 16B. Here we see the same inside pneumatic motor of Fig. 14 attached to the pallet by a wire or tape and held open by (a) the pallet spring and (b) the pressure-wind flowing into it from the windchest through the channel guarded by the disc-valve. But if the disc-valve is lifted up it closes this channel and opens the exhaust-hole to outside air: the pallet-motor immediately collapses and pulls down the pallet. How is the disc-valve moved?

Let us turn to Fig. 16A. This is a tubular-pneumatic touch-box (such as I have in my organ at Stagsden). Here the key is in the normal position: therefore, no sound. Press down the key, and the pallet in the touchbox opens upwards allowing pressure-wind to escape from the small windchest (or pressure chamber) and flow through the tube on the extreme left. We follow the tube to its terminus in Fig. 16B. The pressure-wind now reaches the primary motor, which inflates and lifts the disc-valve above referred to. And that is how the disc-valve is moved, thus exhausting the pallet-motor and opening the pallet. This is, of course, the action of one single key enabling one single pallet to be opened. If all the stops affecting this one particular soundboard are drawn, then every pipe sounding that particular note will speak: all five pipes of the soundboard shown in Fig. 14, for instance, will speak simultaneously: if the key is middle C on the great manual, each pipe will speak middle C so long as the key is held down and the touchbox and soundboard pallets are open. But what happens when the key is released?

The touchbox pallet is closed again, of course, and the soundboard pallet also. Both are closed by their respective springs which are free to act without hindrance. But supposing we strike our key in rapid succession ten times in a second. Will the two pallets open and close completely ten times in that second? Certainly not unless the residual pressure-air in the windchest of the touchbox is able to escape into the atmosphere at the same rate. It can only do this if an exhaust-hole of sufficient size is incorporated in the touchbox itself. This arrangement is shown in the drawing of Fig. 16A. So long as the key is at normal position the exhaust-hole remains open to atmosphere as in the sketch. If the key is **slowly and very gradually** depressed, the pallet slowly and gradually opens (dogging the movement of the key in the opposite direction) **and the exhaust valve as slowly and gradually closes down over the exhaust-hole.** Wind is, therefore, trying to flow through the pneumatic tube on the left, but must at the same time flow along the channel in the direction of the exhaust-hole. A hissing sound will be heard at the exhaust-hole indicating that wind is escaping here till the


Lever
Spring
Exhaust Valve
Exhaust-Hole
To Atmosphere
Pressure Chamber
Pallet Spring
Pallet
Channel
Tube out to Chest Pneumatics
Sticker or Wire
Key

Tubular-Pneumatic Touch-Box

Fig. 16A

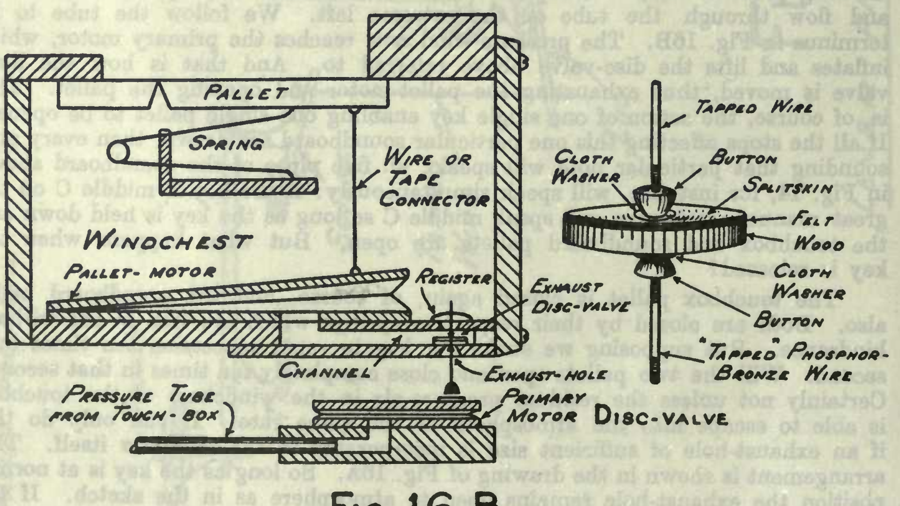
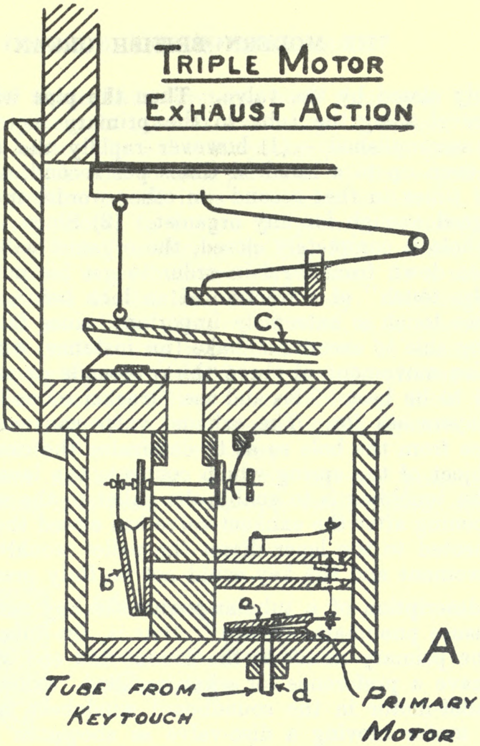
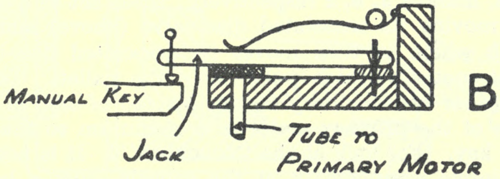

Pallet
Spring
Wire or Tape Connector
Windchest
Pallet-motor
Register
Exhaust Disc-valve
Channel
Exhaust-hole
Pressure Tube from Touch-Box
Primary Motor
Disc-valve
Tapped Wire
Cloth Washer
Button
Splitskin
Felt
Wood
Cloth Washer
Button
"Tapped" Phosphor-Bronze Wire

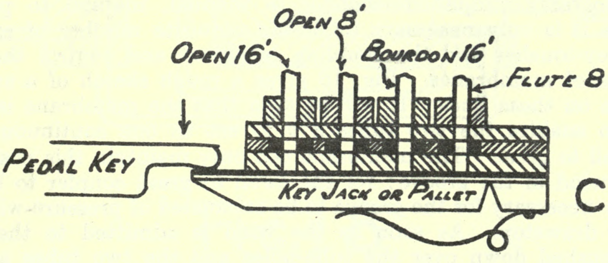
Fig. 16B

TRIPLE MOTOR EXHAUST ACTION


C
b
a
d
A
TUBE FROM KEYTOUCH
PRIMARY MOTOR


MANUAL KEY
JACK
TUBE TO PRIMARY MOTOR
B

EXHAUST KEY-TOUCH


OPEN 8'
OPEN 16'
BOURDON 16'
FLUTE 8
PEDAL KEY
KEY JACK OR PALLET
C

EXHAUST PEDAL-KEY-TOUCH

FIG. 17 A, B, C

hole is completely closed by the valve. **Then the pipe will speak,** for the wind can now only travel along the tube to the primary motor of Fig. 16B. Two things are thus accomplished:—(1) however rapidly the key is struck by the player's finger, even up to a hundred times per second, the pipe will speak the same number of times in that second—in other words, the "repetition," as it is called, will be good enough for any organist. (2) Since the pipe will not speak till the exhaust-hole is completely closed, the organist will have to press the key a certain distance down from level in order to get his note—in other words, he will have a "false touch" of a fraction of an inch before the pipe is allowed to speak. This false touch is extremely important, since it ensures clean playing, the organist being able to execute a shake (for instance) without lifting his fingers too high. A false movement of three thirty-seconds or an eighth of an inch is generally agreed to be best. This and the "tracker touch" with its top resistance is what most players ask for. The exhaust valve can easily be adjusted at the optimum distance from the hole so as to determine the exact degree of false play desired. The object of the spring which connects the lever to the exhaust-valve on the top of the touchbox is to enable the pallet in the windchest of the touchbox to go on opening after the exhaust-valve has closed the hole. If the exhaust-valve were connected to the lever direct the pallet would be unable to make its full opening movement and the key could not be fully pressed down either.

The above description of a tubular-pneumatic key action relates to what is called the "pressure pneumatic system": that is, the touchbox enables pressure-wind to drive the primary motor at the soundboard end of the pneumatic chain. Many builders have a preference for what is called "exhaust pneumatic action," in which the pallet-motor in the soundboard windchest is exhausted not by an outside primary motor moving a disc-valve as shown in Fig. 16B, but by a collapsing primary motor in the windchest itself as shown in Fig. 17A. We have here **three** motors, marked **a, b, c** respectively: these act as a chain, the collapsing primary motor **a** moving its associated disc-valve (above) and so exhausting the secondary motor **b** which in turn moves its associated disc-valve and exhausts the main or pallet motor **c** which pulls down the pallet. The object of having three motors, or rather two auxiliary motors instead of one, is to make it possible to reduce the size of the primary motor to a minimum so that it may be readily exhausted by the key. For look at the "touchbox"! It is not there; in its place we have a very simple arrangement at the console—just a key jack lifted off a hole in a wooden block at the bottom end of which is a pneumatic tube. This tube is connected to the primary exhaust motor at the soundboard. No wonder the exhaust system finds favour with many builders. The coupling arrangements, too, are considerably simplified—manual to manual, manual to pedal, octave couplers—since it is only necessary to fit the requisite number of exhaust tubes between the key-touches and the coupling machines and control the passage of wind by means of membranes. Fig. 18 gives a rough sketch of a swell to great coupling action on these lines. It will be seen that the membrane is in the open position and so enables the two tubes **a b** to act as one continuous tube, thus connecting swell to great. The membrane can only maintain this position if there is no pressure-wind in the groove: for the swell to great coupler to be operative, therefore, it is necessary for the groove to be exhausted of pressure-wind by means of the coupler drawstop. As soon as the wind is admitted to the groove the membrane is pushed down over the tube-holes and the two tubes are separated so that the coupler cannot work. All the various couplers can be similarly arranged.

Both the pressure and the exhaust systems have their **pros** and **cons.** The **tendency** of the pressure system is towards hesitancy of attack, while in point of repetition it is hard to beat. The exhaust system presents just the contrary: it tends to be prompt in attack and to lack precision at the repetition of notes. In order to secure any repetition at all it is necessary to bore a small hole in the top-board of the primary motor to ensure its prompt re-inflation when the key is released. This "bleed-hole" is shown in Fig. 17A. Since it is liable to collect dust in process of time, some builders very wisely fit a set-screw which enables them to adjust the size of the hole to a nicety. Although an exhaust action can be made to work on a light pressure of wind, it is essential to employ a heavy pressure if a really satisfactory repetition is to be secured. Messrs. Harrison and Harrison employ a pressure of 12 in. for their exhaust action; though it is necessary to state that I am referring to examples of their work prior to the adoption of their present excellent electro-pneumatic system such as they installed in their fine organ in Westminster Abbey.

There are two distinct methods of coupling on the pressure system of pneumatic action. Supposing it is desired to couple swell unison, octave and sub-

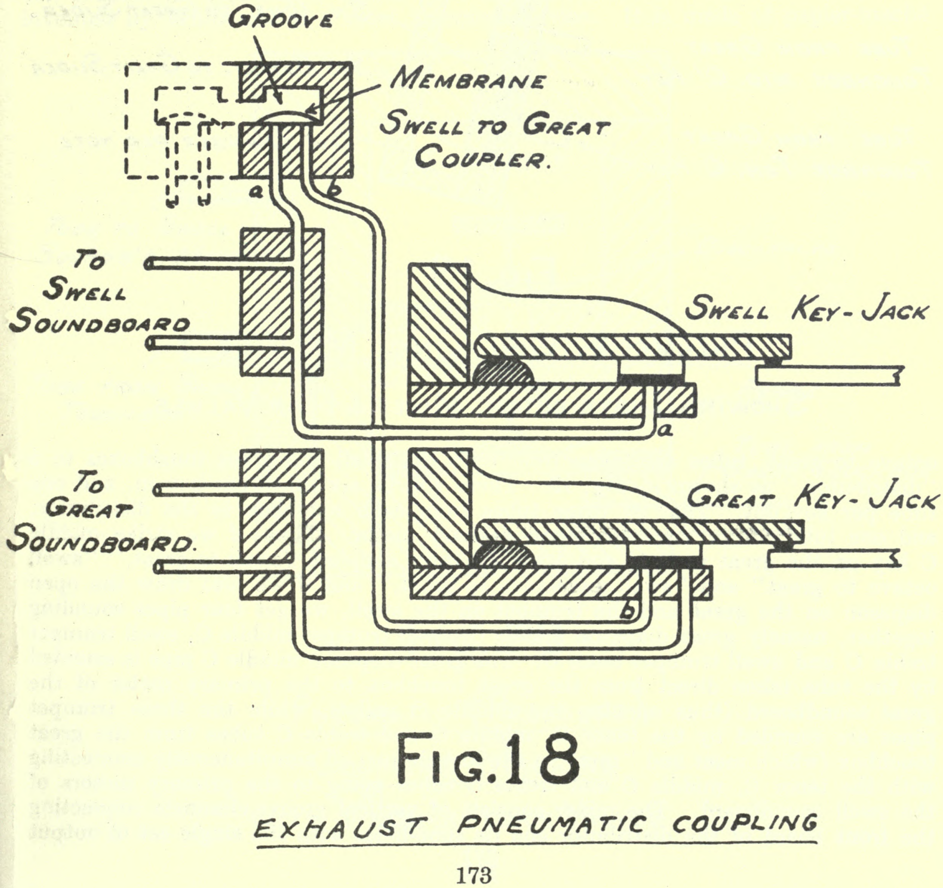


FIG. 18

EXHAUST PNEUMATIC COUPLING

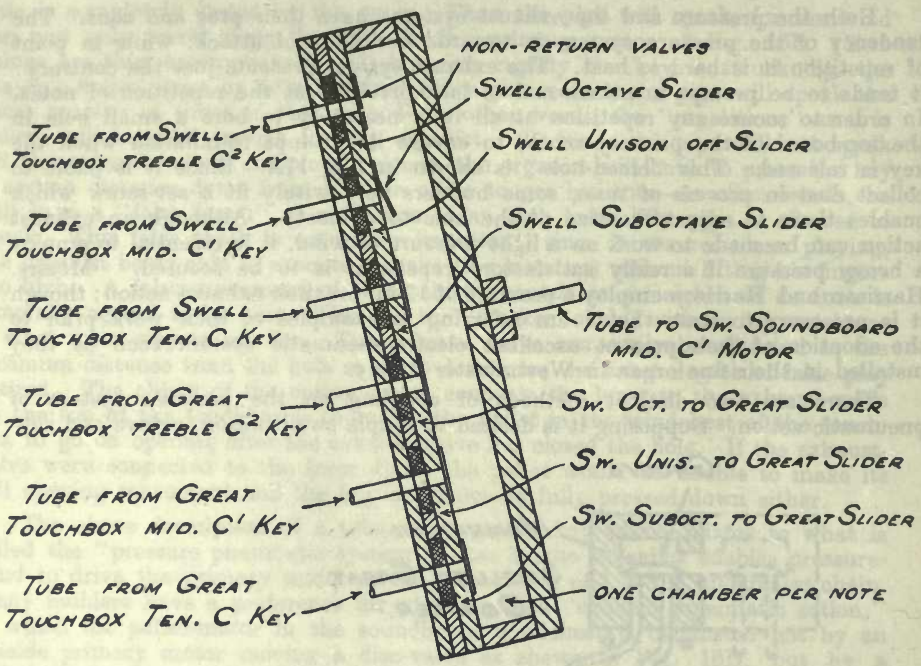

NON-RETURN VALVES
SWELL OCTAVE SLIDER
TUBE FROM SWELL TOUCHBOX TREBLE C² KEY
SWELL UNISON OFF SLIDER
TUBE FROM SWELL TOUCHBOX MID. C¹ KEY
SWELL SUBOCTAVE SLIDER
TUBE FROM SWELL TOUCHBOX TEN. C KEY
TUBE TO SW. SOUNDBOARD MID. C¹ MOTOR
TUBE FROM GREAT TOUCHBOX TREBLE C² KEY
SW. OCT. TO GREAT SLIDER
SW. UNIS. TO GREAT SLIDER
TUBE FROM GREAT TOUCHBOX MID. C¹ KEY
SW. SUBOCT. TO GREAT SLIDER
TUBE FROM GREAT TOUCHBOX TEN. C KEY
ONE CHAMBER PER NOTE

FIG. 19

PNEUMATIC COUPLING MACHINE

SHOWING DISTRIBUTOR, MIXER & FLAP VALVES

octave to great, tubes are taken from both the swell and great touchboxes to a "distributor," as shown in Fig. 19. There will be six tubes per key in, and one tube per key out. That is, three tubes from each touchbox to the distributor, and one tube out to the soundboard primary motor. Thus, if we strike middle C key on the great manual and draw the three couplers "swell to great," "swell octave to great" and "swell suboctave to great," and if we also draw the open diapason on the great and the trumpet on the swell, we get four pipes sounding together, namely great diapason middle C, swell trumpet middle C, swell trumpet treble C and swell trumpet tenor C. The great diapason middle C pipe is sounded by the tube taken direct from the great touchbox to the primary motor of the great soundboard (thus opening the middle C pallet), while the three trumpet pipes are sounded by the tenor C, middle C and treble C tubes from the great touchbox (which meet and "mix" in the distributor) all simultaneously connecting with the tenor C, middle C and treble C tubes going to the primary motors of the swell soundboard. The mixer consists of vertical groove-channels connecting the front board of the distributor and its tube-holes with the single set of output tubes (one per note). This arrangement enables the wind to pass through one, two or three tubes at the other end according to the number of couplers drawn. The drawstops at the console move the sliders shown in the drawing: the "unison-off" slider moves in reverse and shuts off the supply to the unison tube if it is desired to couple the octave and/or suboctave notes to the great without the unison. Octaves up and down on the swell manual itself can be brought on by moving the sliders controlling the tubes from the swell touchbox (with or without unison, as desired) and playing on the swell keys. The non-return valves or "clacks" are necessary to prevent the wind supplied to any one of the coupler tubes from running back to the touchbox and escaping through the exhaust-hole into atmosphere instead of going to the soundboard motor.

A different form of coupling on the pressure system is shown in Fig. 20. When the great manual key is depressed, the pressure-wind in the windchest is able to flow through the output tube to the swell soundboard motor if the disc-valve is raised by the purse below. The latter is inflated by the tube from the great touchbox, the "swell to great" drawstop slider permitting wind to pass. At the same time no wind can flow back through the tube to the swell touchbox because its entrance is closed by a non-return valve. This "V" valve was invented by Willis and is a most ingenious device. It is made of papier-maché

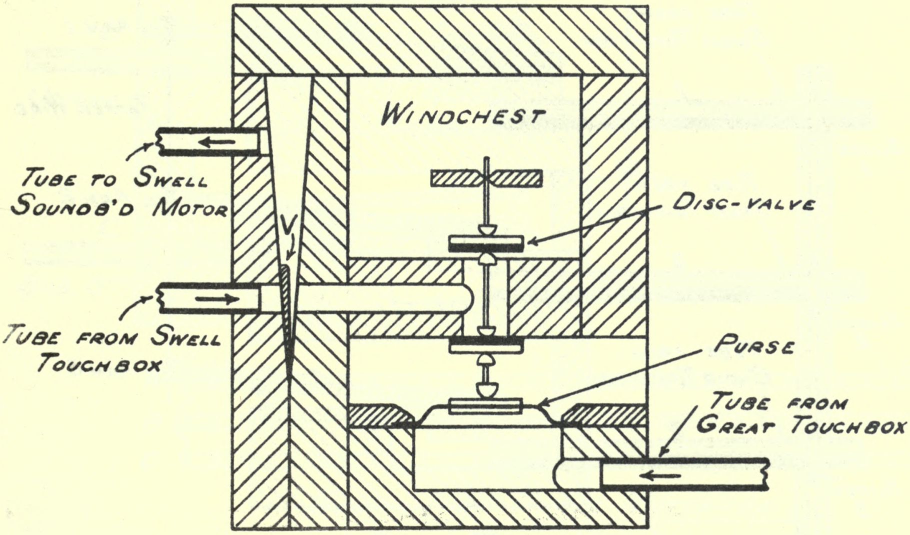


FIG. 20

PNEUMATIC (PRESSURE) COUPLING MACHINE WITH "V" NON-RETURN VALVES

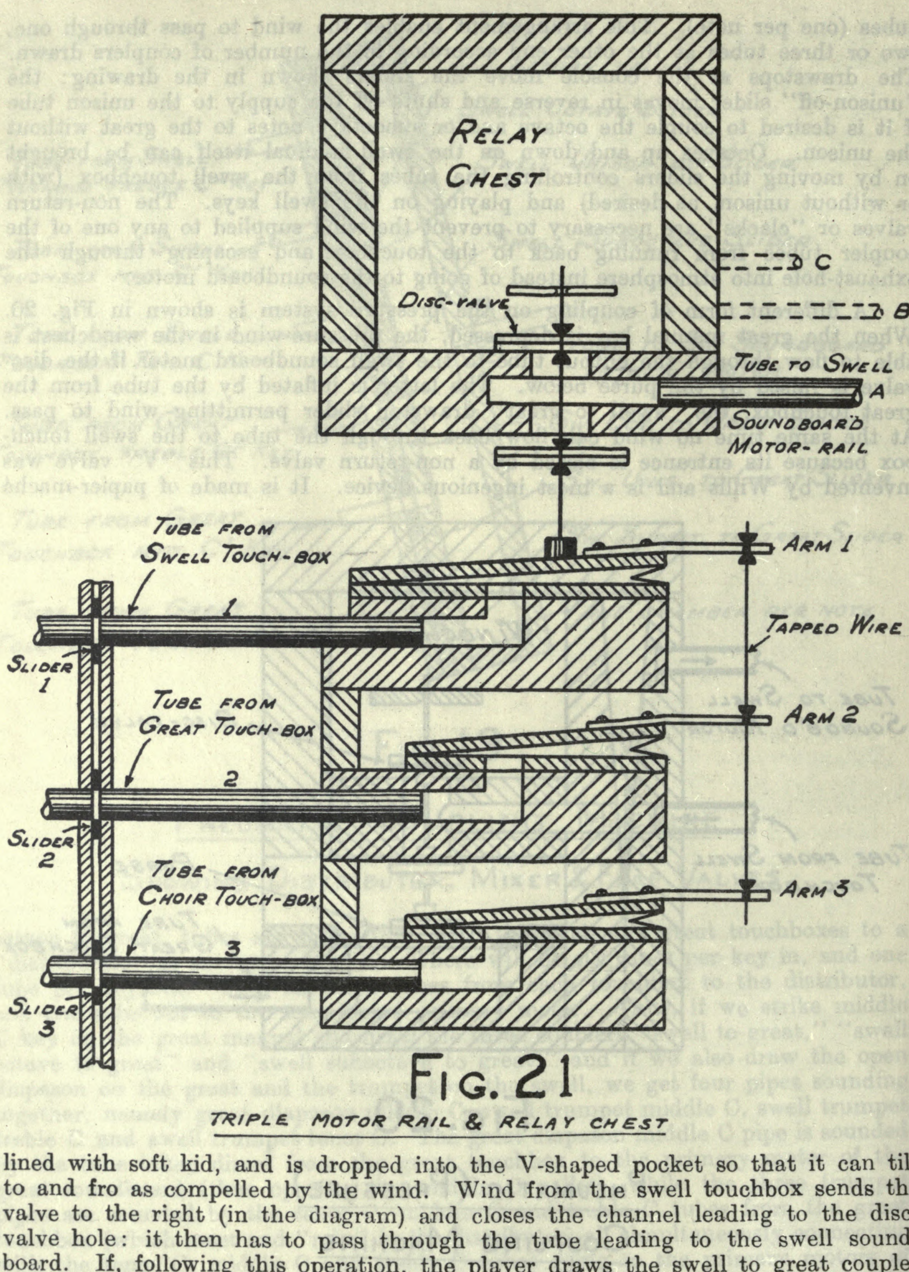

RELAY
CHEST
C
B
DISC-VALVE
TUBE TO SWELL
A
SOUNDBOARD
MOTOR-RAIL
TUBE FROM
SWELL TOUCH-BOX
1
SLIDER
1
ARM 1
TAPPED WIRE
TUBE FROM
GREAT TOUCH-BOX
2
SLIDER
2
ARM 2
TUBE FROM
CHOIR TOUCH-BOX
3
SLIDER
3
ARM 3

FIG. 21

TRIPLE MOTOR RAIL & RELAY CHEST

lined with soft kid, and is dropped into the V-shaped pocket so that it can tilt to and fro as compelled by the wind. Wind from the swell touchbox sends the valve to the right (in the diagram) and closes the channel leading to the disc-valve hole: it then has to pass through the tube leading to the swell soundboard. If, following this operation, the player draws the swell to great coupler and presses a great key, wind flows from the great touchbox, inflates the purse,

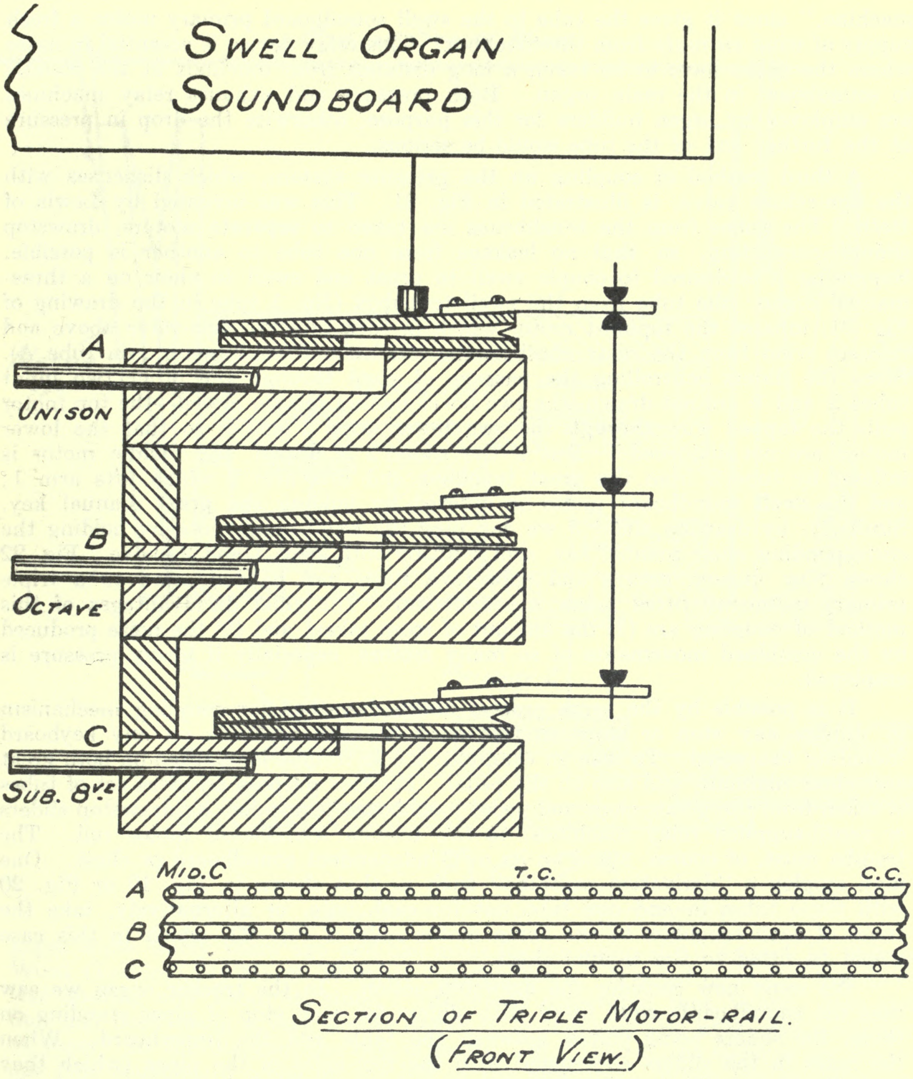

SWELL ORGAN
SOUNDBOARD
A
UNISON
B
OCTAVE
C
SUB. 8VE
MID. C
T.C.
C.C.
A
B
C
SECTION OF TRIPLE MOTOR-RAIL.
(FRONT VIEW.)

FIG. 22

lifts the disc-valve, thus admitting wind stored in the chest to the V-shaped pocket: the V-valve rocks over to the left and the swell manual note sounds. Two or more of these coupling machines can be arranged in cascade on top of one another and connected by tubes for the purpose of adding further couplers such as swell octave and suboctave, unison-off, etc. This machine is really a "relay machine," since it gives the tube to the swell soundboard primary motor a fresh supply of wind *en route* from the touchbox. This relay device is essential in cases where the tubes have to be taken a long distance from touchbox at the console to soundboard in the main organ. Both pressure and exhaust relay machines are employed by organ builders for this purpose, otherwise the drop in pressure at the further end of the tube would be serious.

A third method of coupling on the pressure system, which dispenses with the non-return valve, is illustrated in Fig. 21. This was invented by Lewis of Bath. The tubes from the touchboxes are taken to **separate** motors, drawstop sliders permitting, so that no leakage from one tube to another is possible. Supposing it is desired to couple swell to great and swell to choir on a three-manual organ: the tube from the swell touchbox (No. 1 tube in the drawing of Fig. 21) inflates the topmost motor which in turn lifts the disc-valve above and releases wind from the relay chest to the swell soundboard motor (via tube A). Since the sliders controlling the passage of wind through the other two input tubes 2 and 3 are not drawn, the two lower motors remain closed—the top motor pulls the tapped wire **through** the two lower arms 1 and 2 so that the lower motors are not disturbed. But if the slider 2 is drawn, the middle motor is inflated by tube 2 from the great touchbox and lifts arm 2 which lifts arm 1; and the **swell** soundboard motor is inflated by holding the **great** manual key. Similarly, by drawing slider 3 we can play the swell organ note by holding the corresponding choir manual key, arm 3 lifting both arms 1 and 2 above. Fig. 22 shows how unison, octave and suboctave tubes can be connected to a triple primary motor-rail fitted below a soundboard. The chief disadvantages of this method of coupling are (1) the amount of room taken, and (2) the noise produced by the combined movements of so many motors, especially if heavy pressure is employed.

It is possible by the same process above described for coupling mechanism to duplex any stop or stops so that they may be available on any keyboard including the pedal. To take an example: a solo tromba is required on both great and choir manuals, and also on the pedal. For this purpose an extra set of tubes is taken from the great, choir and pedal touchboxes (controlled by drawstop sliders or ventil-supplied relay machines) to the tromba soundboard motor rail. The tromba must, of course, stand on its own independent soundboard or chest. One may employ a "derivation machine" such as that shown in Fig. 19 or Fig. 20 with three tubes in and one tube out for each note, or alternatively, take the tubes of each touchbox to the three motor rails of Fig. 22, which in this case would be fitted to the tromba chest.

We must now consider the **drawstop** action. In the tracker organ we saw that the soundboards were fitted with sliders for each stop of pipes standing on them, the sliders being placed between the table and the upperboard. When the holes in the sliders correspond with the foot-holes of the pipes (which they do if the stop is drawn) the pipes speak as soon as the keys are depressed. In the direct mechanical system the sliders are worked by trace-rods and trundles as we saw in Fig. 12. Some builders still use slider soundboards, and if it is desired to rebuild an old tracker organ on modern lines without replacing the existing soundboards then some form of pneumatic or electro-pneumatic drive must be devised to operate the sliders. We are at present concerned with pneumatic systems, and it is obvious that the drawstop at the console must energise a pneumatic motor or motors capable of moving the slider in and out. In Fig. 23 is shown a double-motor drawstop mechanism which I worked out on

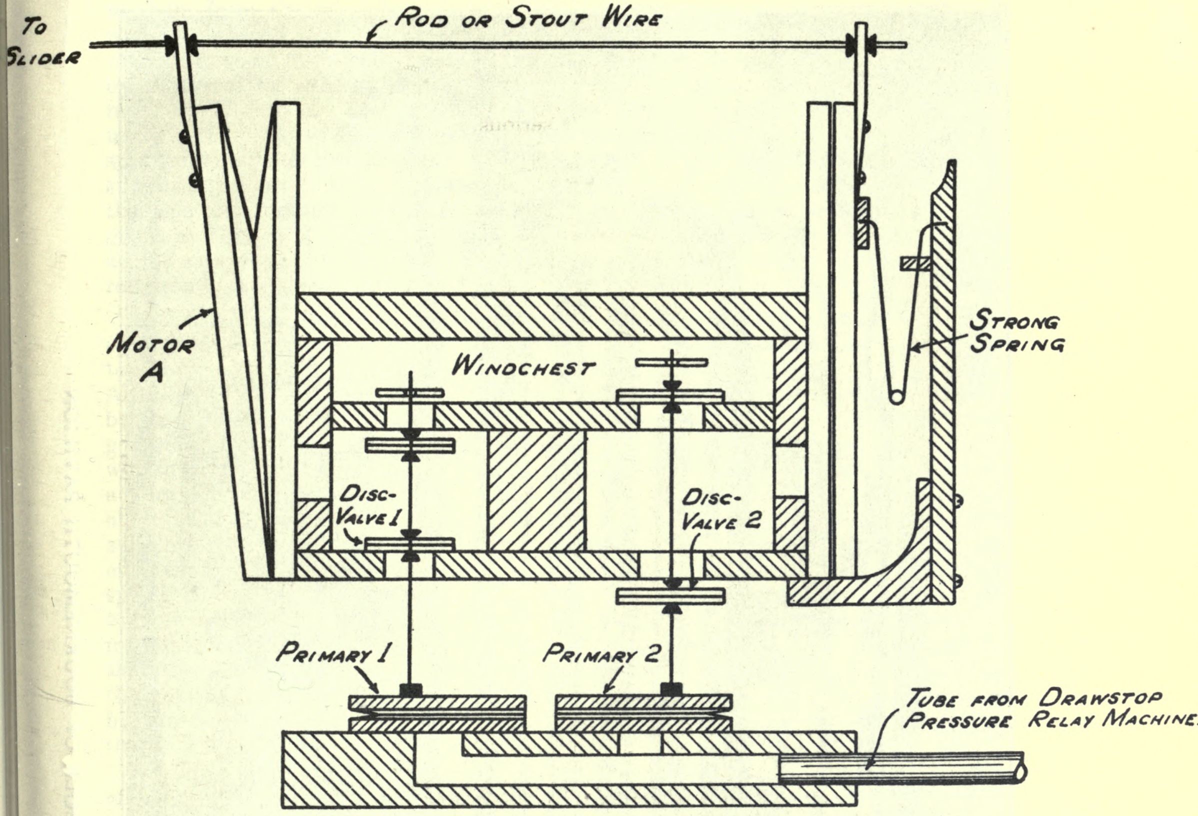
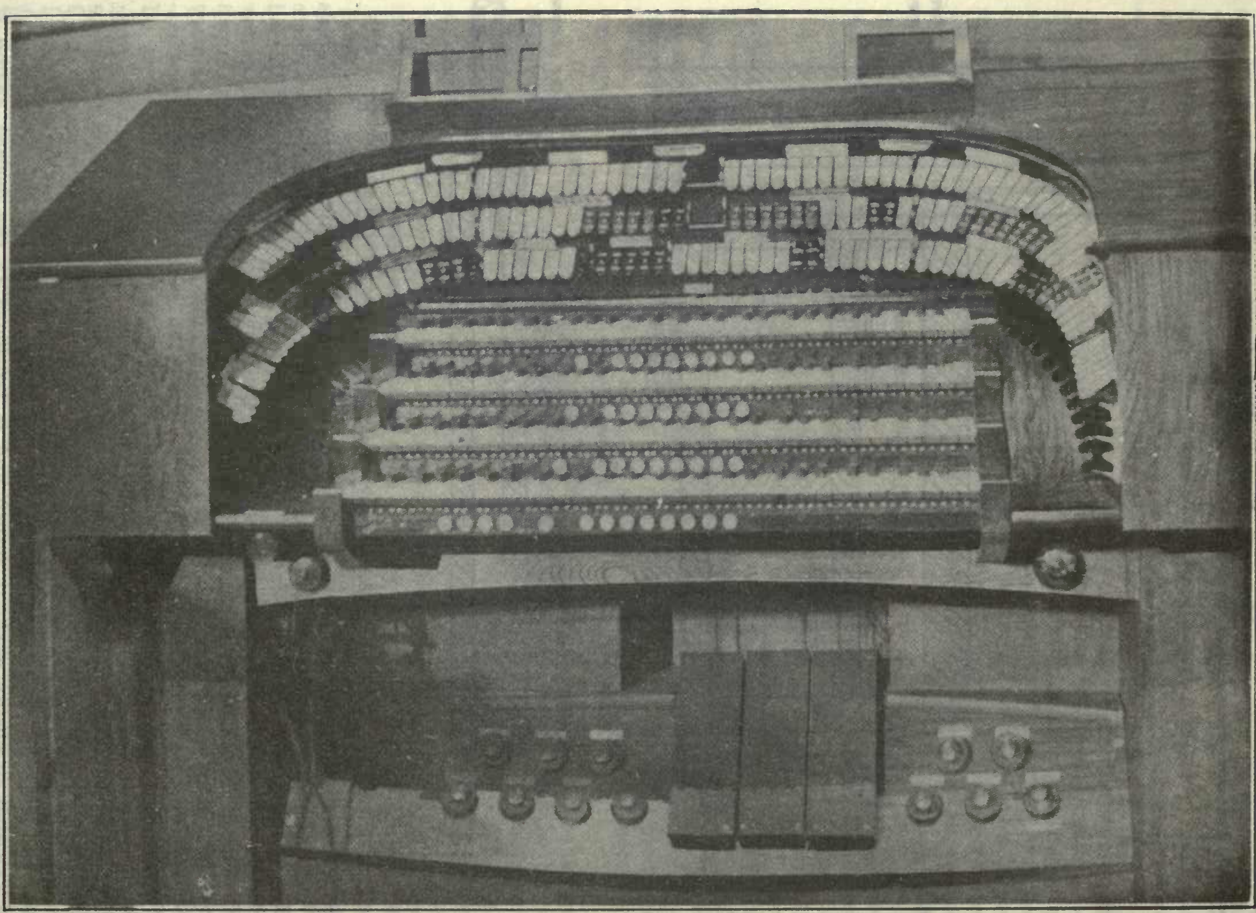

Rod or Stout Wire
To Slider
Motor A
Winochest
Strong Spring
Disc-Valve 1
Disc-Valve 2
Primary 1
Primary 2
Tube from Drawstop Pressure Relay Machine

FIG. 23

DRAWSTOP PNEUMATIC MACHINE.

paper some thirty years ago and had made for the organ at All Saints', St. John's Wood (London), by Mr. S. Wort, of Camden Town. It acted perfectly; but there was nothing new about it, since I afterwards discovered that Messrs. Hill and Son had been using a very similar device in their pneumatic work over a number of years. In the diagram the stop is shown "off," that is, the slider is not drawn out (the soundboard being on the left of the diagram). When the two primary motors are inflated by the tube from the drawstop machine at the console—observe that they are both inflated simultaneously—disc-valve No. 1 shuts off wind from motor A while disc-valve No. 2 admits wind to motor B (from the windchest): consequently the rod connecting the two motors A and B is moved to the right and pulls the slider out the required distance. On the primaries 1 and 2 collapsing as a result of the organist pushing the stop in, the action is reversed and the slider is returned to its off position. The spring on the extreme right is essential to ensure a smart return and is tensioned to the desired degree of resistance. The size of motors A and B depend on the pressure of wind applied



CONSOLE OF BOURNEMOUTH PAVILION

to them from the windchest: my original model worked on 8 in. pressure.. It will be observed that the primaries are inflated by a tube taken from a pressure relay: it would be equally possible to supply wind to these two small motors by means of an exhaust drawstop vent at the console as a study of Fig. 24 will make clear. Here the stop is "on," the tube exhausting through the hole uncovered by the rocker. The motor has collapsed with the pressure of the flat spring above, the disc-valve has opened the channel to wind from the chest and supplied the output tube to the drawstop machine of Fig. 23. A detailed plan of the electro-pneumatic drawstop machine operating the sliders of a soundboard is given in Plates XVI, XVII and XVIII, with an accompanying descriptive note, at the end of this book. This was kindly supplied by Mr. C. H. Clarke and represents the mechanism employed in his own organ at Snaresbrook.

If sliderless soundboards, other than the pitman type, are used—a description of which, together with other types, will be given in the next chapter—it is usual to arrange for the drawstop to supply wind to them by means of a "ventil." Alternatively, the key action may be controlled by a relay machine *en route* between the touchbox and soundboard primaries and the relay machine chest governed by a ventil or else by a slider. Fig. 25 gives a diagram of a ventil working on the exhaust system. The primary motor exhausts through the tube at the console, sends down the disc-valve and cuts off wind from the pressure-chest to the main motor: the latter opens the pallet and a big flush of wind is supplied through the trunk to the soundboard. The reverse movements are effected by the pallet-spring and the bleed-hole working in harmony. The flat spring controlling the disc-valve has also to be nicely adjusted by means of the screw-eye to ensure the primary motor exhausting and re-filling smartly with the movement of the drawstop rod. A word of caution, however: it is very important that the diameter of the trunk supplying the ventil chest should be larger than that of the output trunk to the soundboard chest. This larger size is indicated by the dotted lines in the diagram, the ratio of input to output being not less than 1.5 : 1.

3. The all-pneumatic (like the all-tracker) organ is now out of date: the electro-pneumatic has taken control, and organists will have no other. If it were not for the high consumption of current involved, it is probable that organs would now be all-electric in design and construction on the mechanical side: unfortunately, powerful solenoids are greedy of current, and when (as is necessary) a large number of magnets and solenoids are in frequent use the total current consumed becomes serious. It is, moreover, questionable whether in this country with its very uncertain climatic conditions magnets can be relied upon to perform their duties without rather frequent attention if given too much work to do. It is generally agreed by experts that the minimum of work should be allotted to the magnets and the heavy work left to the pneumatic motors. Modern action is, therefore, electro-pneumatic until some better method is found. However, there can be little doubt that as far as the console is concerned, all pneumatic work is best eschewed (as I have already explained) in favour of electric contact mechanism. The simplification of key, stop, piston and coupling actions is obvious to anyone studying the lay-out of parts and wiring illustrated in Plate X. When the key is pressed, contact B connects with contact C; the contact spring K attached to contact C now engages the rod L which is wired to the soundboard magnet. (What happens then is shown in Fig. 27 which gives a drawing of an electro-pneumatic soundboard action.) The drawstop action here is operated by a stop-key (G), which controls the two-pronged armature of a double core magnet

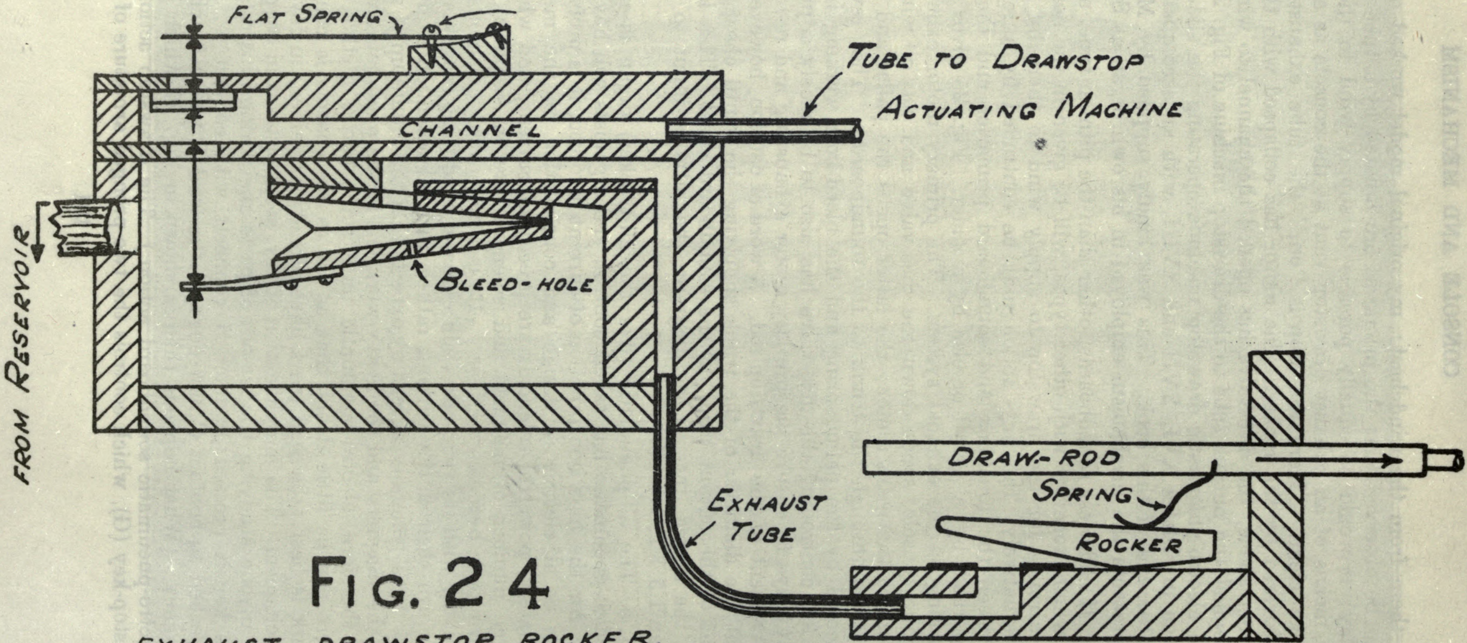

FLAT SPRING
TUBE TO DRAWSTOP ACTUATING MACHINE
CHANNEL
FROM RESERVOIR
BLEED-HOLE
EXHAUST TUBE
DRAW-ROD
SPRING
ROCKER

FIG. 24

EXHAUST DRAWSTOP ROCKER.

R1, R2. When pressed down, the stop-key lifts the armature E so that the two contacts O and J are connected: magnet D is energised and pulls down the contact rod of the ganged switch P which makes contact with the wire K and via L to the pallet magnet. Thus, the manual key contact K cannot energise the soundboard magnet and make the pipe speak until the stop-key is put into action, since the points of contact P, K, L must all three be connected in order to complete the electric current circuit. The other contact wires in parallel with K are employed for coupling other manual keys in unison and octaves, as required, and may also be utilised for duplexing and extending stops on the unit principle. There are as many contact wires per key as there are couplers (or duplicated stops, etc.), four being shown in the diagram; and, of course, each soundboard magnet (in Fig. 27, for example) has its own wire L taken from the ganged switch, one for each note of the manual. The thumb piston H, placed under the key, when pushed in causes the stop-key to drop and so bring on the stop action. The

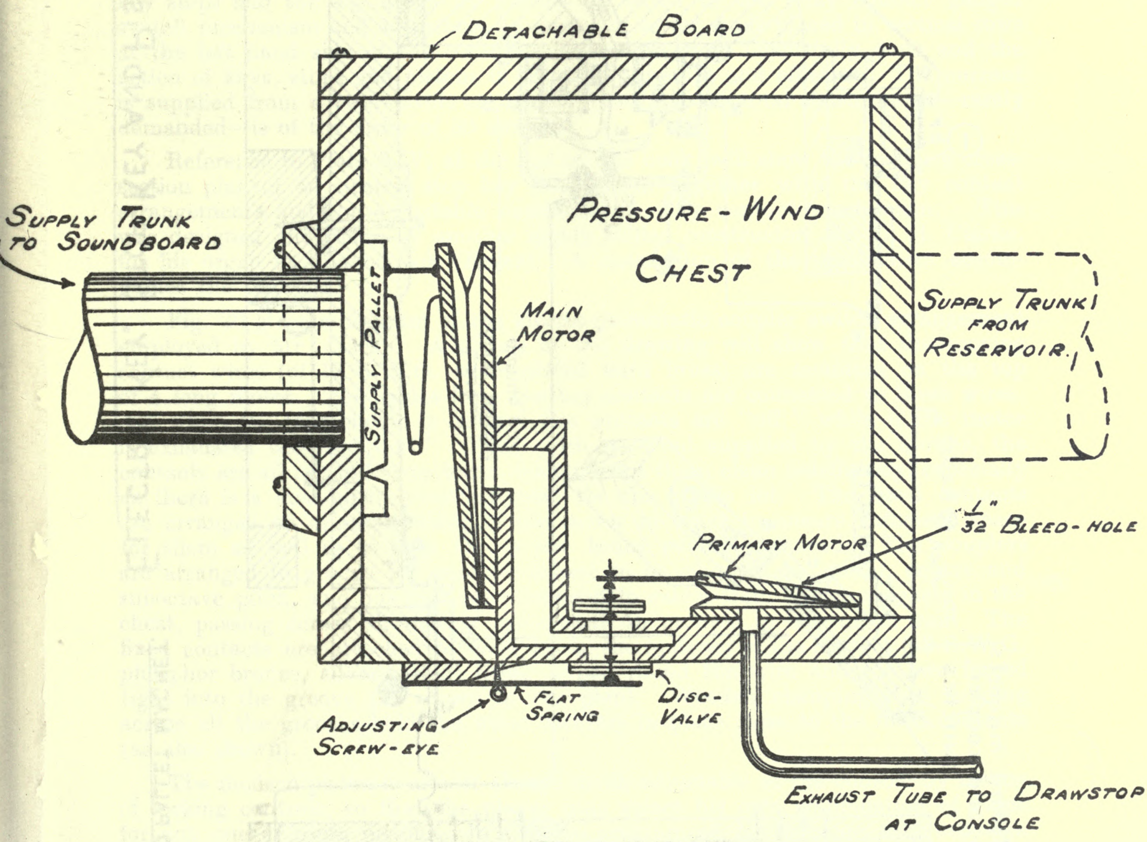
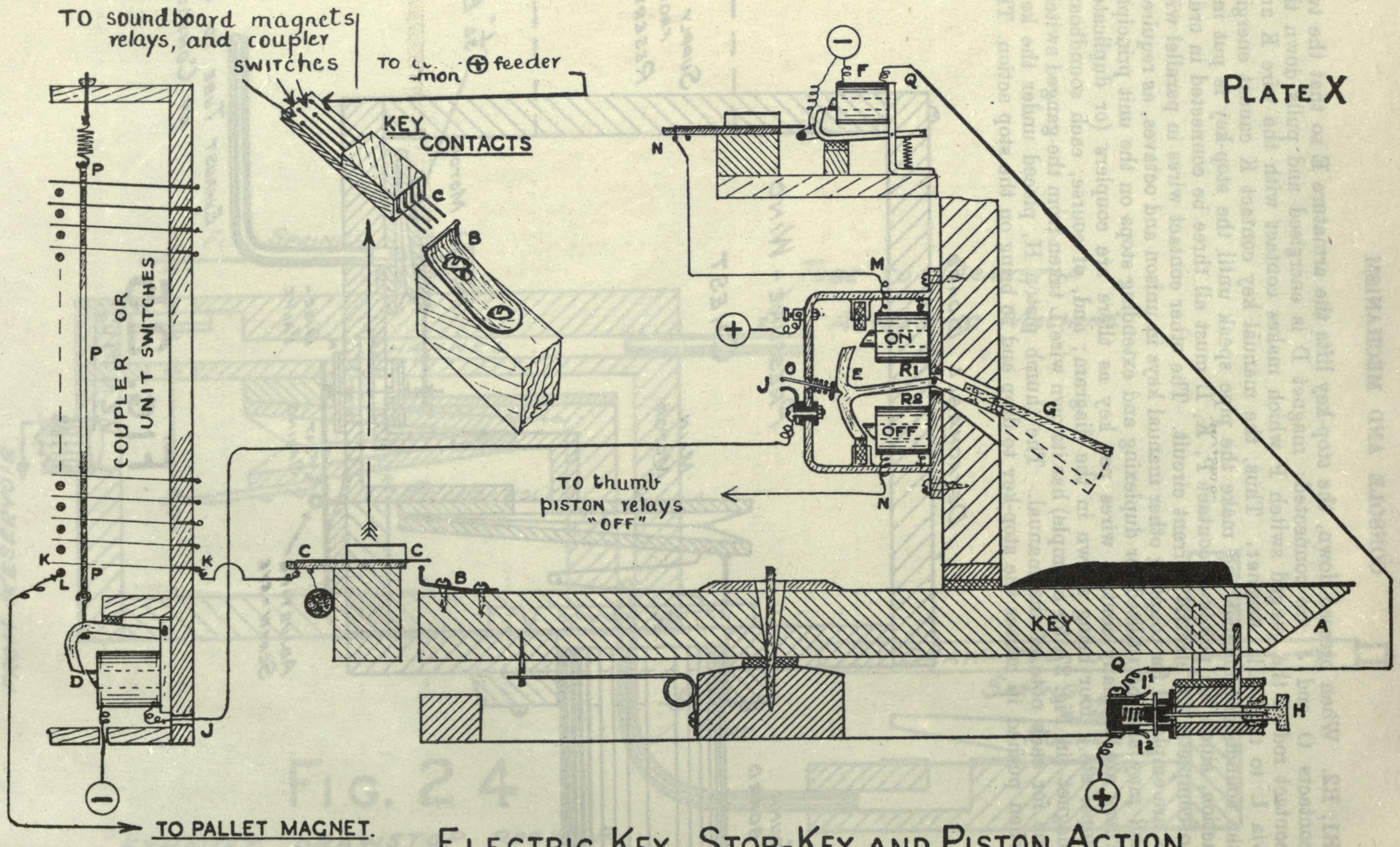

DETACHABLE BOARD
SUPPLY TRUNK TO SOUNDBOARD
PRESSURE - WIND CHEST
SUPPLY PALLET
MAIN MOTOR
SUPPLY TRUNK FROM RESERVOIR.
1/32" BLEED - HOLE
PRIMARY MOTOR
ADJUSTING SCREW - EYE
FLAT SPRING
DISC - VALVE
EXHAUST TUBE TO DRAWSTOP AT CONSOLE

FIG. 25

VENTIL.

PLATE X


TO soundboard magnets relays, and coupler switches
TO com-mon ⊕ feeder
KEY CONTACTS
C
B
P
COUPLER OR UNIT SWITCHES
K
L
P
K
D
J
−
TO PALLET MAGNET.
C
C
B
N
F
Q
−
M
+
ON
R1
R2
OFF
O
J
E
G
N
TO thumb piston relays "OFF"
KEY
A
Q
I1
I2
H
+

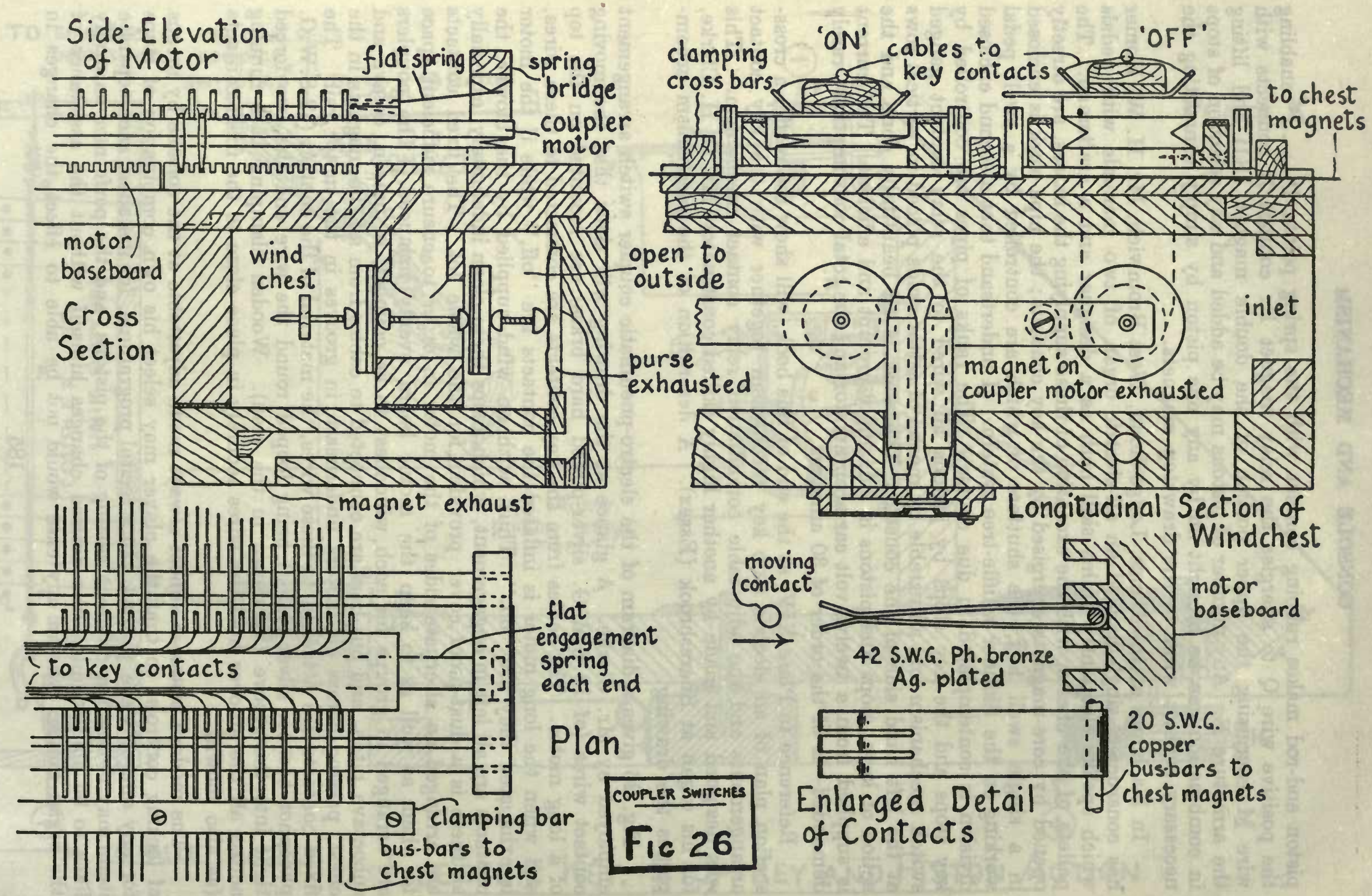
ELECTRIC KEY, STOP-KEY AND PISTON ACTION piston end-rod makes rubbing contact with the spring points $I^1 \ldots I^2$ enabling the positive wire Q to energise the relay magnet F: contact N connects with wire M energising the upper portion of the double magnet (R1) and lifting the armature E. Any number of pistons may be added and any selection of stops in combination can be brought on by any one piston by simply connecting the necessary contact wires to the drawstop magnets.

In his home at the Limes, Lodge Road, West Bromwich, Mr. H. W. Homer has consructed single-handed an all-electric organ of two manuals with pedals which speaks eloquently of his skill both as a designer and a craftsman. The pallets of the chests, with the exception of those supplying the basses, are directly opened by core-magnets energised by the key contacts; the pipe-work is enclosed in a single swell box, the shutters of which are controlled by a swell pedal working on the Skinner whiffle-tree system. (I undertsand that a second enclosed division is contemplated in due course.) The ranks of pipes are controlled by key stops and the key stops by pistons all wired to the relay contact ganged switch mechanism and adjustable by means of setter studs placed in vertical rows at the left hand side of the console. The work is all beautifully done and the action of keys, stops and pistons is amazingly prompt and efficient. The current is supplied from a twelve-volt car accumulator and the total consumption—rarely demanded—is of the order of 30 amperes.

Reference to Plate XIV, at the end of this book, will show the reader a cross-section plan of an electric stop key mechanism together with the key contact arrangements and the adjustable combination relay contact mechanism. This was designed and made by another highly skilled constructor, Mr. C. H. Clarke, for his organ at Snaresbrook (Essex). A description of the mechanism accompanies the drawing.

Fig. 26 gives a diagram of the electro-pneumatic coupler switch arrangement employed by Mr. Clarke. A glance at the drawing will show that the moving contact wires (of 18 S.W.G. silver-plated hard brass) are mounted on the top of a long motor. The cables from the key contacts are connected to these wires, and when the long motor is inflated the contacts are "off," while if the motor is exhausted they are "on." Thus, with no wind supplied by the blower, the contacts are all left in engagement, which keeps them clean indefinitely, especially as there is a dust-proof cover provided for the whole lot. The fixed contacts are arranged on alternate sides of the motor in order to ensure sufficient space for them as well as to keep the motor board evenly balanced. The couplers are arranged in groups for each windchest to be coupled, in unison, octave and suboctave pitch, and bus-bars are connected to cables from all the magnets in the chest, passing across all motors underneath in grooves in the motor rail. The fixed contacts are attached to these wires, the material of the contact (42 S.W.G. phosphor bronze, silver-plated) being looped round the wire and the two forced tight into the groove (as shown in the plan). Wooden clamping bars running across all the grooves hold the wires securely in place close to the fixed contacts (as also shown).

The modern piston is almost always made adjustable at the console by means of locking controls, so that the player may select his own combination of stops for any one or more pistons. In a recital programme, for instance, each separate item may demand a different setting of the pistons, and the performer naturally likes to be able to make the desired changes himself without the assistance of the organ builder who in any case would not be able to effect the changes in


Side Elevation of Motor
flat spring
spring bridge
coupler motor
motor baseboard
Cross Section
wind chest
open to outside
purse exhausted
magnet exhaust
clamping cross bars
'ON'
cables to key contacts
'OFF'
to chest magnets
inlet
magnet 'on' coupler motor exhausted
Longitudinal Section of Windchest
to key contacts
flat engagement spring each end
Plan
clamping bar
bus-bars to chest magnets
moving contact
42 S.W.G. Ph. bronze Ag. plated
motor baseboard
20 S.W.G. copper bus-bars to chest magnets
Enlarged Detail of Contacts

COUPLER SWITCHES

FIG 26

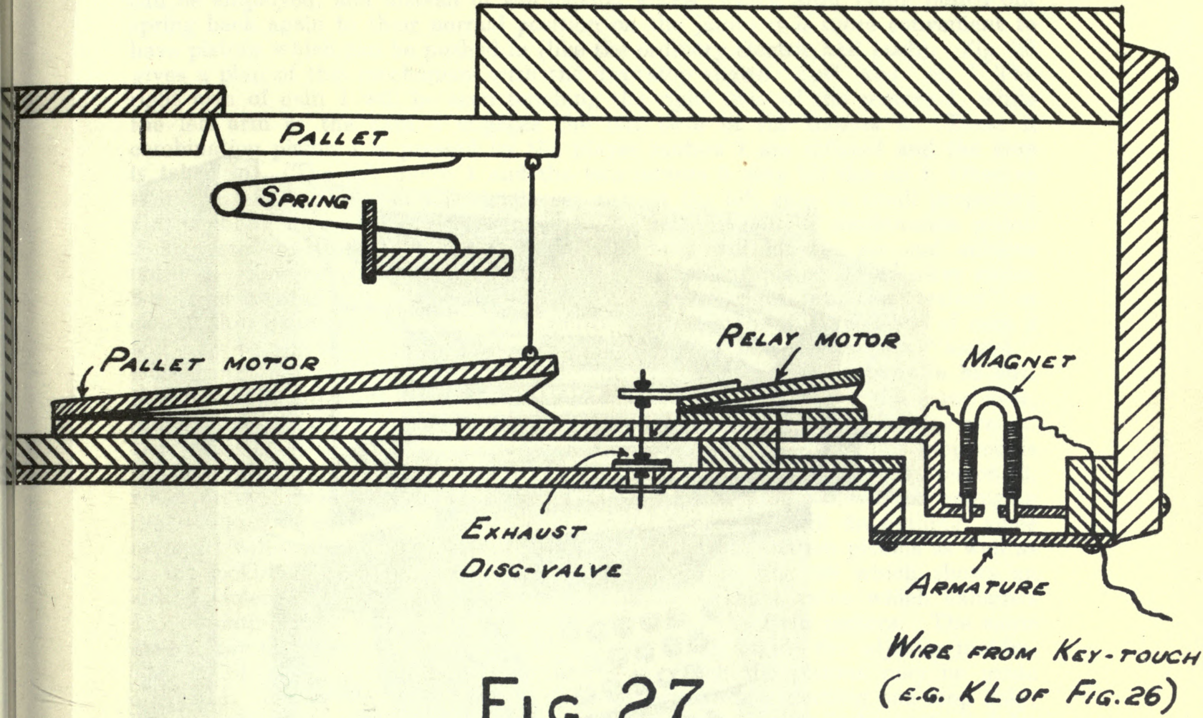
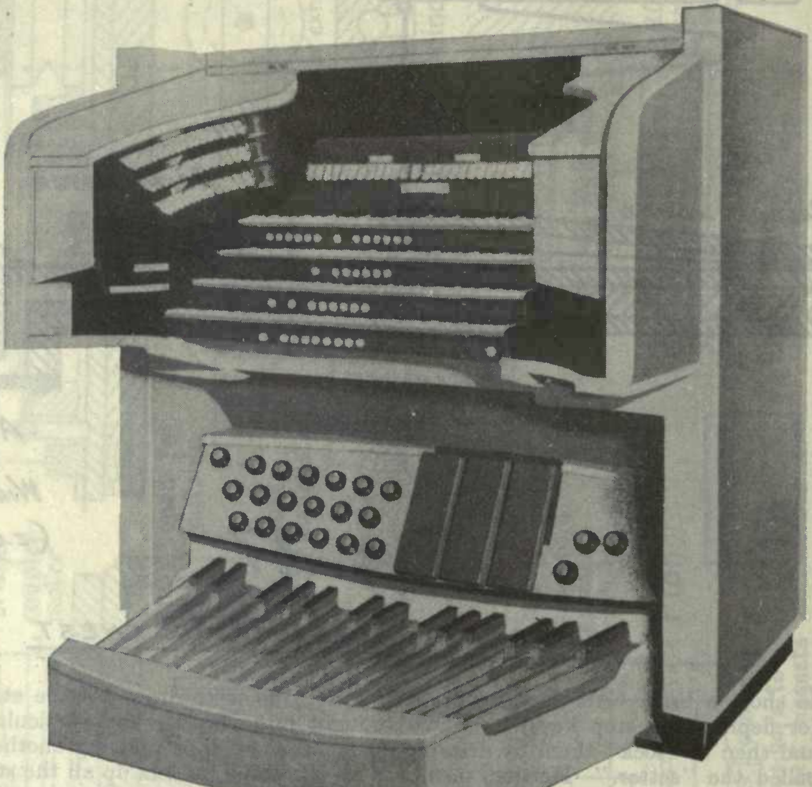


FIG. 27

ELECTRIC PNEUMATIC CHEST.

so short a time. All that the organist has to do is to draw out the stop-knobs (or depress the stop keys) he wants brought into play by any particular piston and then to "lock" them by drawing out another knob or pressing another piston called the "setter." He then pushes in all the stops (or lets up all the stop keys) and whenever that particular piston is pressed those stops will come on. If he wants to alter the combination again he can do so by the same process.

The adjustable piston was popularised by J. J. Binns about half a century ago when he introduced his "patent interchangeable combinations" into his organs. The drawstops were actuated by large pneumatic motors which worked mechanical fans, and the fans in turn made contact with blocks which were attached to the stop-rods. In place of these blocks Mr. Binns substituted specially shaped cams pivoted to the stop-rods: these cams formed the basic principle of his interchangeable piston mechanism. By means of "locking stop-knobs" he was able to shift the cams over to such a position on the draw-rod as would enable the fan to engage them or prevent the fan from engaging them as required. I remember how struck I was with the cleverness of this device when I examined for the first time his arrangement of the combination pistons at All Saints', St. John's Wood. Instead of mechanical fans, however, twin motors



CONSOLE OF WOLVERHAMPTON CIVIC HALL

can be employed, and instead of the locking knobs (which after being pulled out spring back again to their normal position on the jamb) it is more convenient to have pistons which can be pushed in (like the ordinary electric bell push). Fig. 28 gives a plan of this mechanism with the drawstop shown "out" and "on." The right arm of cam 1 will be seen touching the right twin of the motors 1, while the left arm of the cam 2 engages the left twin of the motors 2. Thus, if combination piston 1 is pressed by the player motors 1 are inflated **and the stop is taken in.** (The left motor 1 and the two motors 2 only hit the air.) Observe that the left arm of cam 1 is rigidly set against the left stop (a small projecting pin) enabling motor 1 to drive the rod to the left. Again, if combination piston 2 is pressed by the player, the inflated motors 2 will hit the air and achieve nothing. Now supposing the player presses the **locking** piston 2: adjuster motor 2 will be inflated and down will fall the adjuster 2 right into the "valley" of cam 2 thus swinging the cam over against the left stop. The position of cam 2 will now be the same as that of cam 1 which the player has just "locked." Both combination pistons will now take the draw-rod in **if it happens to be out.** Note that the adjusters, after having done their work of swinging the cams over, immediately return to *status quo* as soon as the player releases the locking piston. Let us go back to the diagrammed positions of cams 1 and 2. The stop-rod is shown drawn fully out. Suppose it is pushed in: then combination piston 2, when pressed, will draw the stop out, since the left motor 2 will be engaging the left arm of cam 2; combination piston 1, if pressed, will do nothing, since motors 1 will miss the cam. The mechanism of the combination pistons as well as of the locking pistons at the console is also given in Fig. 28 which shows an electric solenoid controlling the movement of an exhaust valve which exhausts a pneumatic motor and so admits pressure-wind to the twin motors. The same action may be employed for the locking pistons which supply the adjuster motors. This is, of course, only one of many ways in which the pistons may be made operative. I have explained the functions of two pistons working one stop only, but in order that all the stops of a department may be similarly controlled by adjustable pistons it is necessary to arrange the stop-rods, motors, cams and adjusters in a vertical column.

If adjustable pistons are introduced in an all-electric console, since there is no wind available and therefore no pneumatic mechanism, recourse has to be made to magnets only for the operation of the various controls.

Fig. 29 shows in simplified form a diagram of the all-electric combination action on the "capture" system with electric drawstops as used by Messrs. Henry Willis and Sons. **All** the pistons in this system are adjustable at the console by means of a **single** locking piston. When the locking piston (not shown) is at rest, the switch A is closed and the switch B is open. If the locking piston is pressed in, switches A and B are reversed. Should the organist wish to set a combination of stops on any given piston he first draws the stop or stops required and then presses the locking piston, thus reversing the switches A and B. He must hold the locking piston in and press the combination piston also. The contact F will now cause the "on" solenoid at G to reverse the contact at D and prepare it to feed the "on" bus-bar. He next releases both the locking and the combination piston. Next time the latter is pressed, the stop (or stops) will come on. It will be noted that the combination piston, when pressed, closes the contacts at C so that a positive charge passes through either the "on" or the"off" bus-bars at D, which latter are connected with the "on" and "off" solenoids according to whether the contact at D has been set "on"

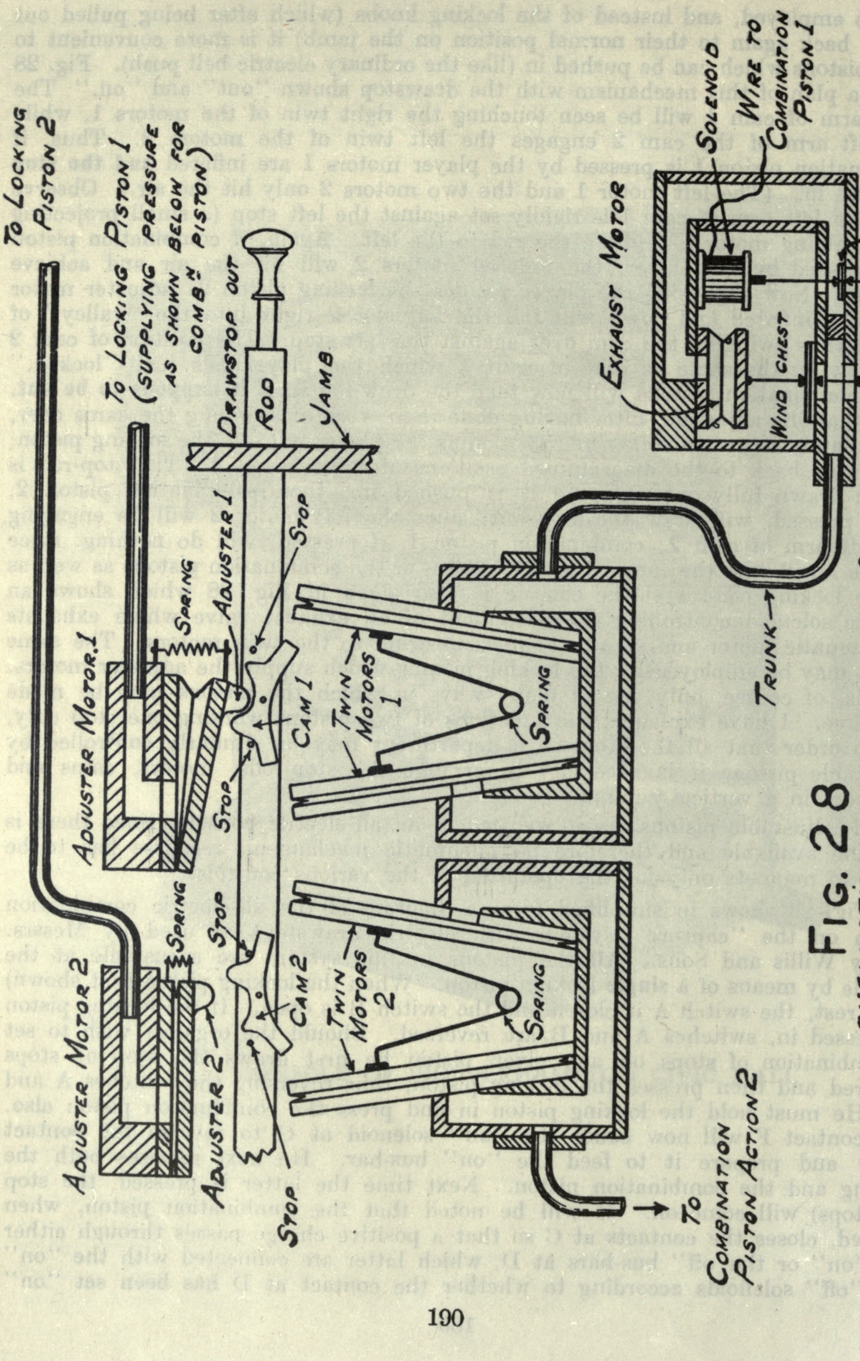
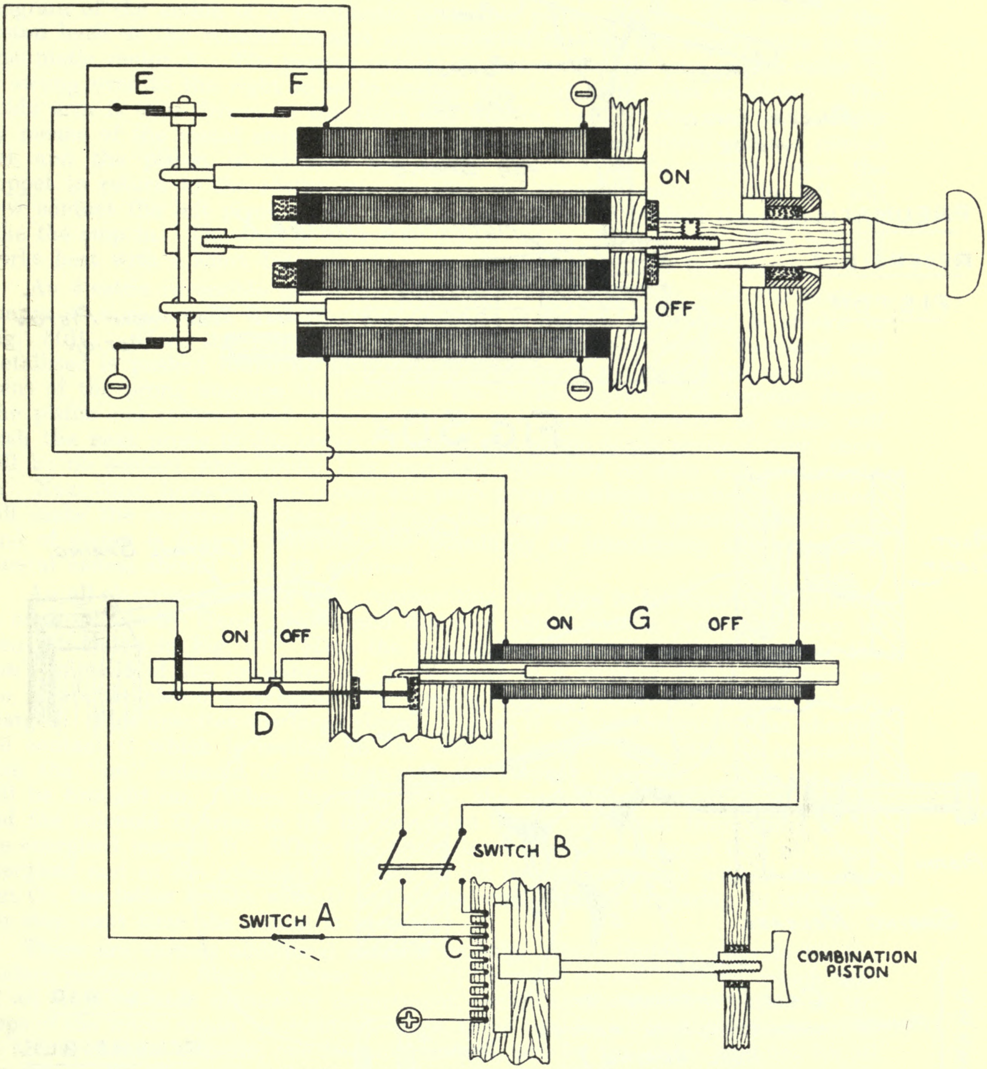

To Locking Piston 2
To Locking Piston 1 (supplying pressure as shown below for comb.n piston)
Drawstop out
Rod
Jamb
Exhaust Motor
Solenoid
Wire to Combination Piston 1
Exhaust Valve
Wind chest
Supply Valve
Trunk
Adjuster Motor 1
Spring
Adjuster 1
Stop
Cam 1
Stop
Twin Motors 1
Spring
Adjuster Motor 2
Spring
Stop
Adjuster 2
Cam 2
Stop
Twin Motors 2
Spring
To Combination Piston Action 2

FIG. 28
PNEUMATIC ADJUSTABLE PISTON ACTION.

or "off." The sketch in Fig. 29 is purely diagrammatic in order not to confuse the reader with technical details of construction.

There are certain stops (solo stops in particular) and couplers (swell to great, swell to pedal, great to pedal) which the player likes to be able to bring on or off as desired independently of the combination pistons or pedals. For this purpose


E
F
ON
OFF
ON
OFF
G
ON
OFF
D
SWITCH B
SWITCH A
C
COMBINATION PISTON

WILLIS ADJUSTABLE PISTON ACTION.

FIG 29

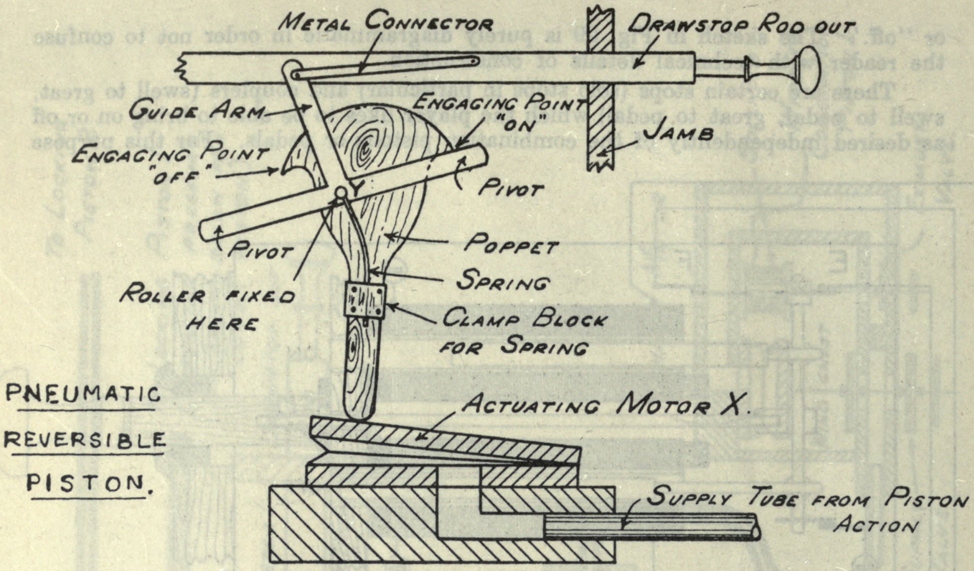

METAL CONNECTOR
DRAWSTOP ROD OUT
GUIDE ARM
ENGAGING POINT "ON"
JAMB
ENGAGING POINT "OFF"
PIVOT
PIVOT
POPPET
SPRING
ROLLER FIXED HERE
CLAMP BLOCK FOR SPRING
PNEUMATIC REVERSIBLE PISTON.
ACTUATING MOTOR X.
SUPPLY TUBE FROM PISTON ACTION

FIG. 30A

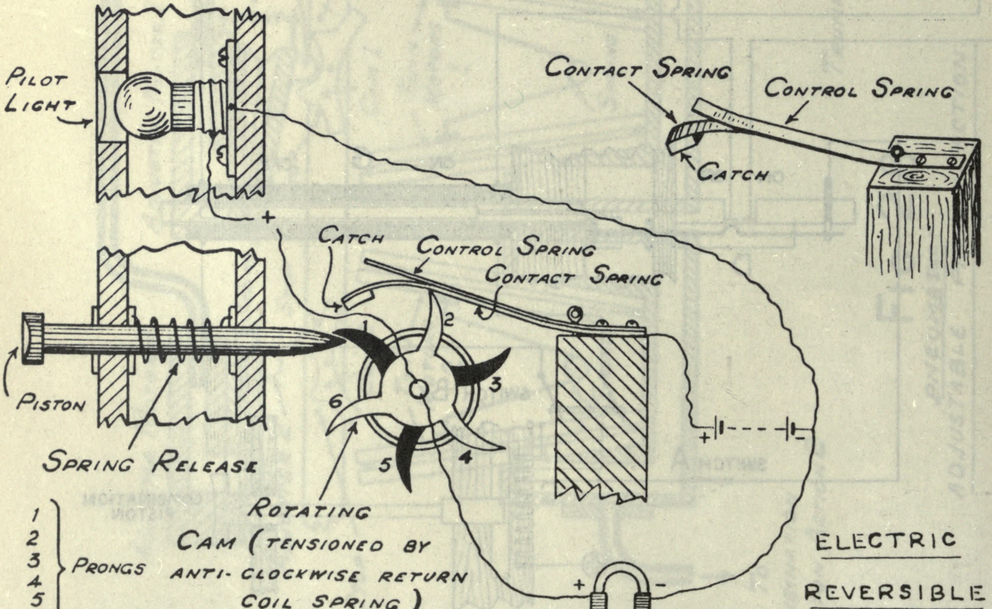

PILOT LIGHT
CONTACT SPRING
CONTROL SPRING
CATCH
+
CATCH
CONTROL SPRING
CONTACT SPRING
1
2
3
4
5
6
PISTON
SPRING RELEASE
+
-
ROTATING CAM (TENSIONED BY ANTI-CLOCKWISE RETURN COIL SPRING)
1 2 3 4 5 6 } PRONGS
+
-
ELECTRIC REVERSIBLE PISTON

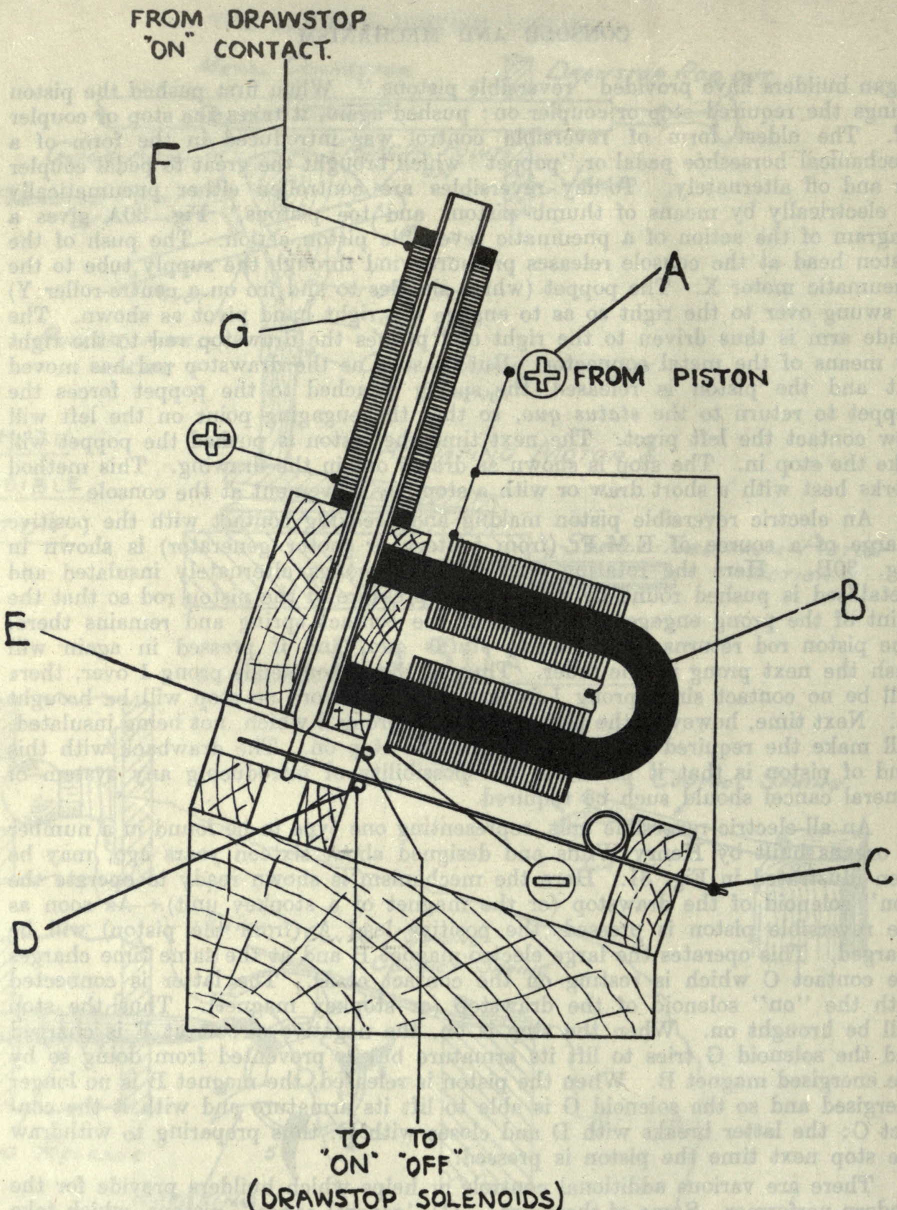
FIG. 30B

organ builders have provided "reversible pistons." When first pushed the piston brings the required stop or coupler on: pushed again, it takes the stop or coupler off. The oldest form of reversible control was introduced in the form of a mechanical horseshoe pedal or "poppet" which brought the great to pedal coupler on and off alternately. To-day reversibles are controlled either pneumatically or electrically by means of thumb pistons and toe pistons. Fig. 30A gives a diagram of the action of a pneumatic reversible piston action. The push of the piston head at the console releases pressure-wind through the supply tube to the pneumatic motor X. The poppet (which shuffles to and fro on a centre-roller Y) is swung over to the right so as to engage the right hand pivot as shown. The guide arm is thus driven to the right and pushes the drawstop rod to the right by means of the metal connector. But as soon as the drawstop rod has moved out and the piston is released, the spring attached to the poppet forces the poppet to return to the *status quo*, so that the engaging point on the left will now contact the left pivot. The next time the piston is pushed the poppet will take the stop in. The stop is shown as drawn out in the drawing. This method works best with a short draw or with a stop-key movement at the console.

An electric reversible piston making and breaking contact with the positive charge of a source of E.M.F. (from battery or motor generator) is shown in Fig. 30B. Here the rotating cam with its prongs alternately insulated and metallised is pushed round by each inward pressure of the piston rod so that the point of the prong engages the catch of the contact spring and remains there. The piston rod returns each time to *status quo*, and if pressed in again will push the next prong in due order. Thus, if the piston sends prong 1 over, there will be no contact since prong 1 is insulated; therefore no stop will be brought on. Next time, however, the piston will push prong 6 which, not being insulated, will make the required contact and bring the stop on. The drawback with this kind of piston is that it precludes the possibility of introducing any system of general cancel should such be required.

An all-electric reversible unit, representing one type to be found in a number of organs built by Henry Willis and designed about sixteen years ago, may be seen illustrated in Fig. 31. Here the mechanism is shown ready to operate the "on" solenoid of the drawstop (or the magnet of a stopkey unit). As soon as the reversible piston is pressed, the positive lead A (from the piston) will be charged. This operates the large electro-magnet B and at the same time charges the contact C which is resting on the contact at D. The latter is connected with the "on" solenoid of the drawstop (or stopkey magnet). Thus the stop will be brought on. When the stop is on, the negative circuit at F is charged and the solenoid G tries to lift its armature but is prevented from doing so by the energised magnet B. When the piston is released, the magnet B is no longer energised and so the solenoid G is able to lift its armature and with it the contact C: the latter breaks with D and closes with E, thus preparing to withdraw the stop next time the piston is pressed.

There are various additional controls or helps which builders provide for the modern performer. Some of these are:—(1) "general cancel" pistons, which take off all stops on each manual or department, including the pedal, and also all the stops of the whole organ, as required. Thus, there may be six such pistons provided on a four-manual console, one for each manual, one for the pedal, and one for all the stops. (2) Pistons to take the couplers all off. (3) Rocking tablets to switch any combination of stops or any tonal department on to any manual; e.g. swell 16 ft., 8 ft., and 4 ft. chorus reeds to choir or to pedal—meaning that these


FROM DRAWSTOP "ON" CONTACT.
F
A
G
FROM PISTON
+
+
B
E
C
−
D
TO "ON"
TO "OFF"
(DRAWSTOP SOLENOIDS)

One type of "Willis all-electric reversible unit."

FIG 31

reeds are no longer playable on the swell manual since they are transferred to the choir or to the pedal. (4) Double touch pistons or key-stops: the first touch takes the key down or pushes the piston in the usual distance from normal position, while a further movement in the same direction constitutes the second touch. (See Fig. 32, which illustrates a double touch piston movement.) Hope-Jones introduced this idea in the form of a double key touch on the manual, the second touch bringing on a solo stop or any stop selected by the builder. The John Compton Organ Company employ double touch pistons which serve various purposes. In their fine organ at the Pavilion, Bournemouth, they have provided eight double touch pistons to each manual, the first touch controlling manual stops in the ordinary way, the second reducing the pedal stops to a very soft combination: there are also four more of these pistons controlling the "bombarde" department, as well as second touch cancelling pistons. (5) Special purpose pistons: (a) reducing the whole organ to a soft combination of stops on

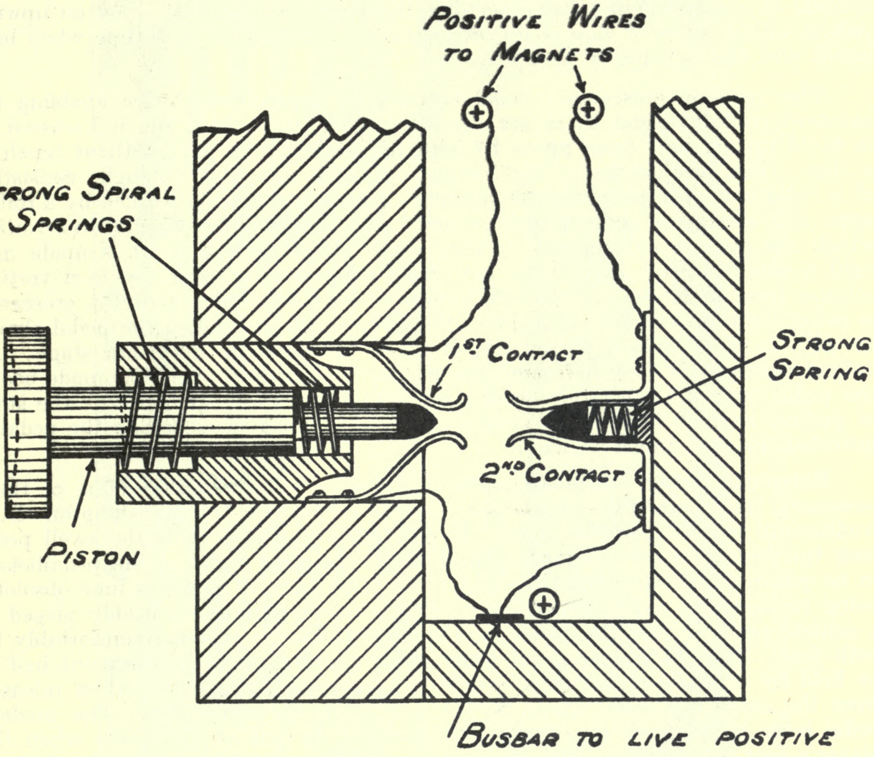


FIG. 32

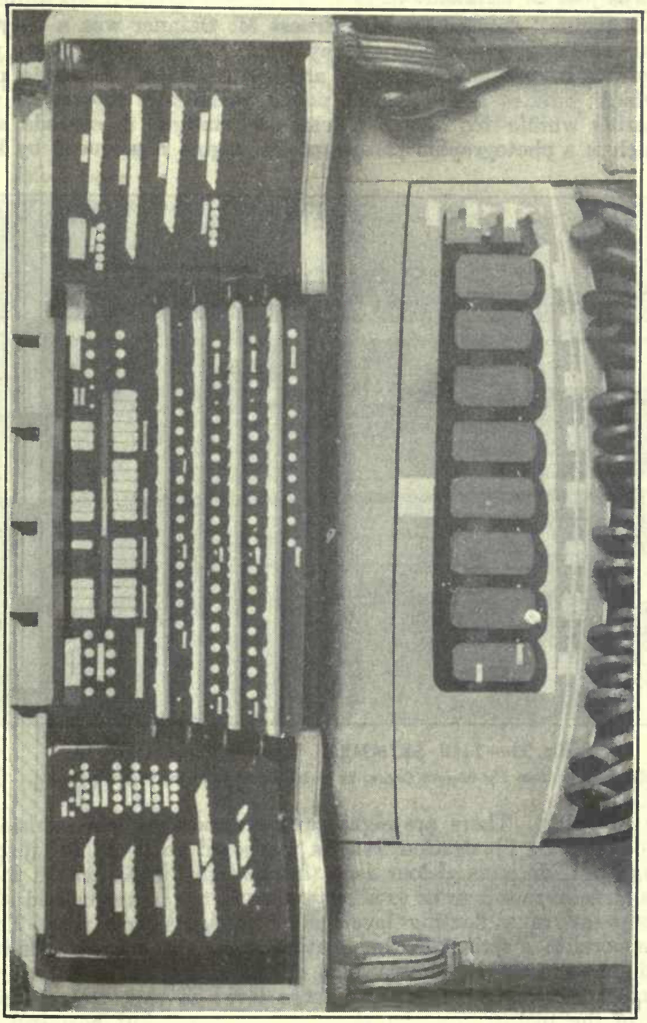
DOUBLE TOUCH PISTON

all manuals with appropriate pedal; (b) controlling other pistons! (c) coupling or uncoupling swell pedals and the general crescendo pedal; (d) providing suitable pedal bass to manual combinations; (e) connecting pedal pistons to manual pistons and *vice versa.*

Messrs. Kingsgate, Davidson Co. sometimes provide a great to pedal (or swell to great, as desired) reversible knee-bar of wood placed under the lowest manual in a convenient position so that the player can operate it by an upward jerk of either knee—a very useful arrangement for a player at a time when both hands and feet are busily occupied.

The "general crescendo" pedal is a highly appreciated device enabling the harassed recitalist—and there **are** occasions when he is very much harassed!—to build up his tone from **pp** to **fff** with the desired gradation without touching a stop. The mechanism, if electrically operated, is simple enough, consisting of a balanced lever pedal for the organist's foot, a contact rod worked by a roller-arm, and a series of contact springs (one for each stop to be brought on *seriatim*) which the contact rod engages in succession. Each contact as it is made may light a small electric glow lamp, and these lamps can be arranged in a vertical column from under up, so that the player can see to what extent the crescendo is being built up or at what point in the build up he has taken the pedal should he wish to make only a partial use of it, or to reduce to a certain stage. An optical indicator is essential, since the player may forget that he has made use of the pedal on a previous occasion or a few minutes ago and wonder why the stops or pistons are not functioning properly. Even if a piston cancelling the pedal is provided, he may forget to use it.

Reference to the six photographs of consoles will show that none of them possesses less than two swell pedals, while that of the Washington D.C. Auditorium has as many as eight. In the older type of console the swell pedal took the form of a trigger lever placed at the extreme right of the pedalboard, to be pumped by the organist's right foot. This form of pedal is now obsolete, being replaced by the balanced lever pedal which is almost invariably placed in a central position over the pedal keys so that it can be reached comfortably by both feet. The old trigger pedal when brought down to its lowest point had to be held by a notched rod which would engage it at that point: when released from the catch the pedal would fly up and close the swell box. The modern pedal lever is balanced on a centre pin and can be left at any point when the player's foot is removed. The object of the pedal is to open and close the shutters or louvres which are fitted to the front (or any) panel of the swell box, thus producing crescendo and diminuendo effects (or, as E. H. Lemare was fond of doing, sforzando effects). If the console is attached or not too far away, these shutters may be controlled by means of a series of rods and squares, with ball-bearing connections. But if the console is at some distance from the shutters such mechanical connection becomes a difficult proposition. It is not impossible under any circumstances, as the amazingly clever mechanical arrangement by Messrs. Norman and Beard at St. Luke's, Redcliffe Square (London) testifies. Here the connecting rod runs the entire length of the roof of the north aisle, the console being in the chancel and the organ in the west gallery. Naturally, organ builders have not been slow to avail themselves of pneumatic and electric agency in finding a solution of this problem of remote control. At first, the crude idea was tried of fitting a pneumatic motor to each shutter and arranging for the movement of the swell pedal to open one shutter at a time: this did **not** solve



MOLLER CONSOLE IN WASHINGTON, D.C., AUDITORIUM

the problem for the simple reason that (1) the sudden opening of the first shutter released too much power at the initial movement of the pedal and (2) the successive opening of the remaining shutters produced a series of jerks in volume-increase instead of a smooth and gradual crescendo. The reverse effect (diminuendo) was just as unsatisfactory.

The "swell engine" devised by Mr. Ernest M. Skinner was a very definite advance on all earlier electro-pneumatic systems. The swell pedal makes a number of contacts in the usual manner and each contact puts into operation mechanism which inflates a number of paired pneumatic motors to which is attached a floating whiffle-tree lever. These are arranged in cascade as shown in Fig. 33, which is a photographic picture of the engine reproduced by kind permission of the inventor. There are eight square motors in each division of the windchest (which in the illustration has its faceboard removed for inspection): these are "staggered" in rows of four each (in the right hand division the second motor in front is seen raised so as to allow a view of the motor behind it). Each motor draws one end of a floating lever as it exhausts upwards. This lever is connected in turn to a series of other floating levers. A large whiffle-tree lever will be noticed underneath the chest. The object of the series of levers in the chest is to control the movement of this large lever so that the square shown at the bottom of the picture may be given a very small but powerful pressure in either direction. This square is connected to the trace-rod that moves the shutters directly. The mechanism is in effect geared down from the first lever to the last so as to produce a gradual opening and closing of the swell box. There is not in my opinion **absolute** control over this motion over the complete range since, theoretically, this can only be effected by an infinite number of levers:

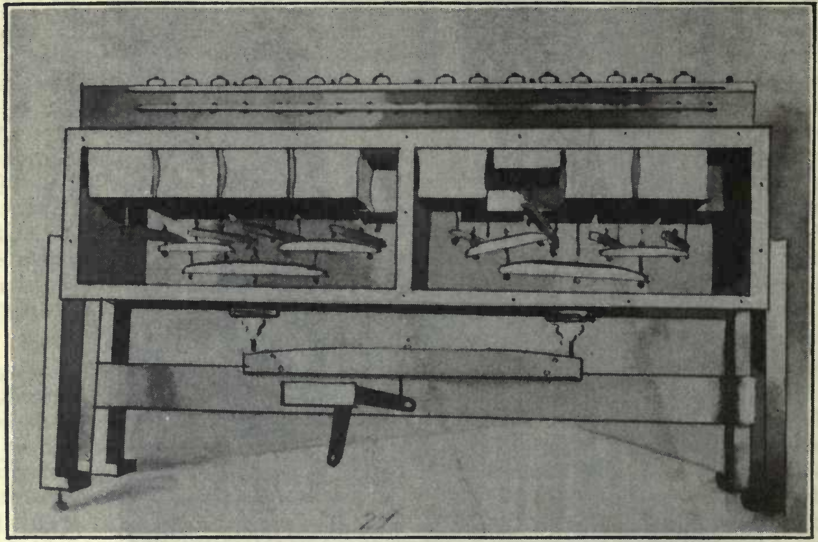
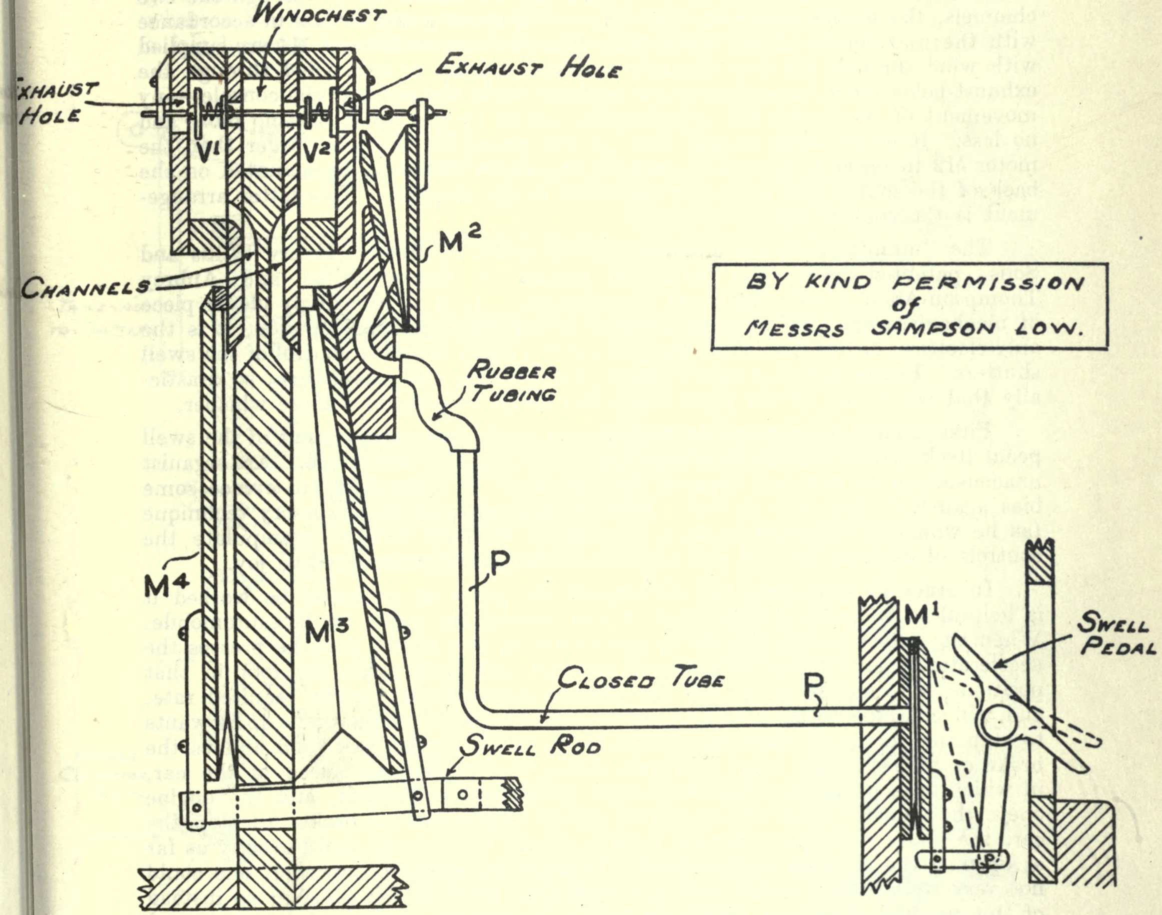


Fig. 33—THE SKINNER Swell Engine.
(Reproduced from *The Modern Organ*, by E. M. Skinner, by kind permission.)

as many as thirty-two "stations" were incorporated in the Willis version of this swell engine at Liverpool Cathedral, yet it could not be said with truth that the control was as complete as would be provided by a direct mechanical connection to the swell pedal. Since then Messrs. Henry Willis and Sons have installed their "infinite-speed-and-gradation swell pedal" which I shall describe in a later paragraph.

It should be noted that in Mr. Skinner's arrangement the shutters are held open by a spring; thus, the motors relax to open the shutters and exhaust to close them, so that, with no wind on, the shutters are always open. A sforzando


WINDCHEST
EXHAUST HOLE
XHAUST HOLE
V1
V2
M2
CHANNELS
RUBBER TUBING
P
M4
M3
CLOSED TUBE
P
SWELL ROD
M1
SWELL PEDAL

BY KIND PERMISSION of MESSRS SAMPSON LOW.

FIG. 34

ROOSEVELT PNEUMATIC SWELL PEDAL.

effect is ensured by the motors all moving at once. That Mr. Skinner ha evolved a really clever piece of mechanism is not open to question, and it is b no means the only product of his fertile brain.

A purely pneumatically operated swell pedal is that illustrated in Fig. 34. It was invented by Roosevelt, and is quite the best type for a console situated not too far from the swell shutters, as, for instance, in a house. The balanced pedal at the console works a motor M1 and controls the motor M2 by means of the closed tube P . . . P. Free motion of this tube is ensured by the flexible rubber tubing which joins the two ends of the metal piping. The trace-rod connected to the swell shutters is moved to and fro by the two opposing motors M3 and M4: these are fed with wind from the windchest above through the two channels, the double-beat disc-valve V1 . . . V2 opening and closing in accordance with the movements of the motor M2. The two motors M3 and M4 are supplied with wind through the two channels as above stated, or exhausted through the exhaust-holes above, according as the organist works the pedal at the console—any movement of the motor M1 is beautifully copied by the motor M2, no more and no less. It is necessary to add that (a) the motor M1 must be larger than the motor M2 in order to govern it, and (b) the motor M2 must be mounted on the back of the motor M3, as clearly indicated in the diagram. This latter arrangement is the soul of the mechanism.

The "infinite-speed-and-gradation" swell pedal of Messrs. Henry Willis and Sons, patented under the combined names of Henry Willis and Aubrey Thompson-Allen, must next claim our attention. It is an amazingly clever piece of mechanism and, if I may be allowed to express a personal opinion, it is the only electrical device that offers the performer a really **intimate** control of the swell shutters. Furthermore, it really **closes** the shutters, and closes them so drastically that the sound of the pipes inside the box is reduced to a mere whisper.

First of all it is necessary to describe the action and management of the swell pedal itself which represents a new departure in pedal technique. An organist unaccustomed to this new type of "pedipulation" is quite likely to evince some bias against it; but only at first. Once he has acquired the necessary technique (as he would be expected to do if he wished to learn how to manipulate the controls of his car), he will exchange his initial prejudice for positive joy.

In order to appreciate the working of the pedal as it should be worked it is helpful to compare it with that of the accelerator pedal of an automobile. When the driver wishes the car to move forward at a snail's pace he presses the accelerator pedal forward the desired amount and then holds the foot in that position. The engine drives the car forward automatically at the required rate, and will continue to do so so long as the foot is kept in this position. If he wants to stop the car he releases the accelerator by removing his foot (and applies the brake or brakes). He may, however, desire to increase the speed of the car, in which case he presses the accelerator pedal farther forward, and the engine obeys the signal. With the exception of the application of brakes to stop the car, the above description fits the working of the Willis swell pedal exactly as far as opening the shutters is concerned. To close the shutters, however, one could not very well have a clutch and a reverse gear lever at the console; so instead of this method of control which we find in a car, the swell pedal is balanced halfway in a neutral position. If the player presses the pedal forward with the toe he is pressing it against the resistance of a spring (as with an accelerator pedal), **and the pedal will spring back to this neutral position on release of the foot.**

But the shutters of the swell box **remain at the point at which the foot was released from the pedal.** In order to close the shutters the pedal is pressed downwards by the organist's heel from its neutral position and against another spring. Thus, one can stop the shutters opening or closing at any point, at any desired speed, simply by **relaxing the foot.**

Let us now turn to the shutters themselves. It is essential for the designer of a swell pedal control mechanism to realise the important fact that the sound of the enclosed pipes is not increased in power in direct ratio of the opening of the shutters: in other words, if one wishes to obtain an evenly proportioned crescendo it cannot be obtained by opening the shutters at a fixed rate of progression. As the shutters open so the crescendo effect will be less and less audible: whereas the first half-inch or so of opening makes a great difference and releases a fair increase of volume from the pipes, the last inch or so of movement is

PLATE XI

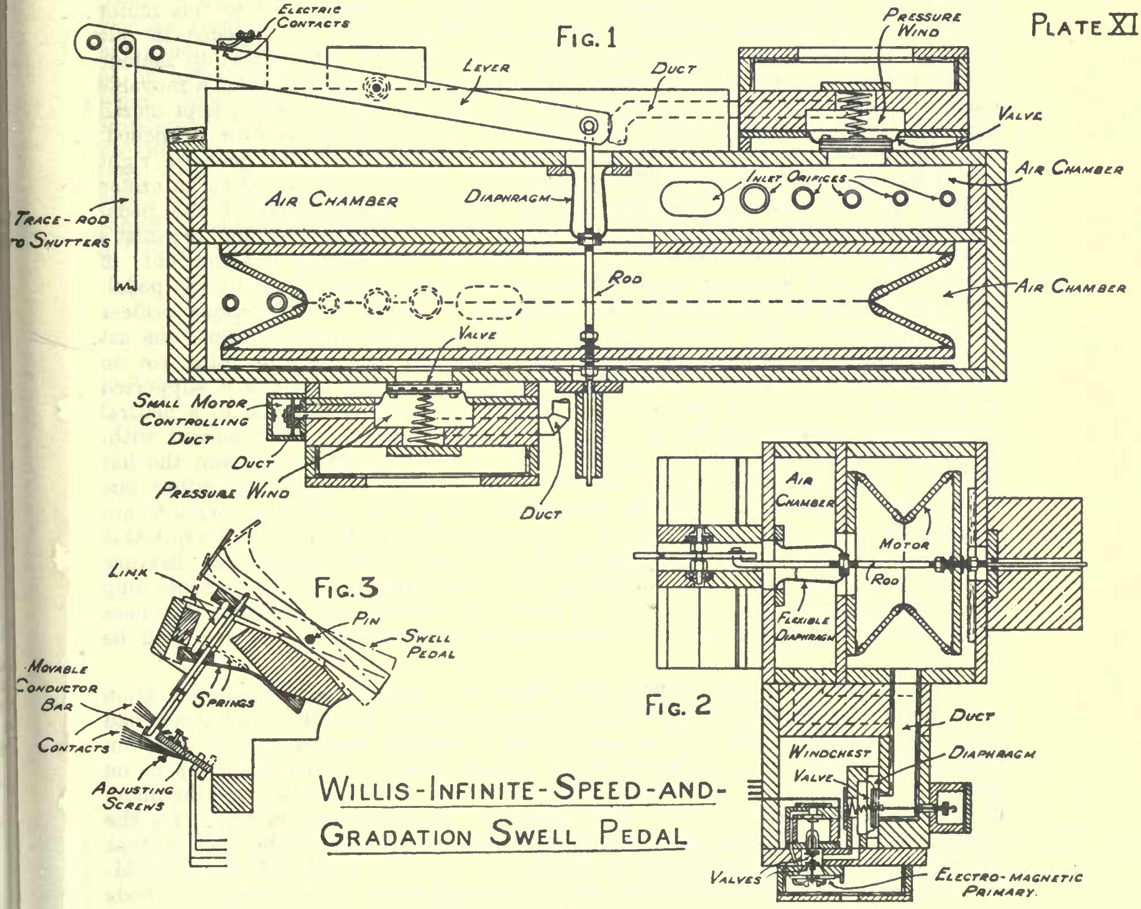


FIG. 1
Electric Contacts
Lever
Duct
Pressure Wind
Valve
Air Chamber
Inlet Orifices
Diaphragm
Air Chamber
Trace-rod to Shutters
Rod
Air Chamber
Valve
Small Motor Controlling Duct
Duct
Pressure Wind
Duct
FIG. 3
Link
Pin
Swell Pedal
Movable Conductor Bar
Springs
Contacts
Adjusting Screws
FIG. 2
Air Chamber
Motor
Rod
Flexible Diaphragm
Duct
Windchest
Diaphragm
Valve
Valves
Electro-magnetic Primary.

WILLIS-INFINITE-SPEED-AND-GRADATION SWELL PEDAL relatively ineffectual. To overcome this Messrs. Willis apply to the swell engine an automatic accelerator device which makes the shutters open at an ever-increasing speed as they approach the fully open stage. When the shutters are being closed, a decelerator decreases the speed of the shutter movement as the fully closed position is approached. An optical indicator at the console tells the organist and reveals the position of the shutters. I have already pointed out that the shutters when closed are squeezed tight by the engine which has no springs opposing it: thus, the maximum of crescendo and diminuendo range is effected. Far too many swell boxes fail to close properly: at least, that is my own experience.

By the kindness of Mr. Willis I am able to show the diagram of this swell pedal action, which the reader may digest at his leisure. It will be seen that the swell shutter trace-rod is moved by a large motor, and it is obvious that this large motor top-board is in some mysterious way under complete control of the swell pedal. How is this achieved? The supply of pressure-wind to this motor is beautifully graduated by means of orifices of increasing size opened in due order by the pedal movement. The motor, moreover, is constructed to include two wind receiving chambers respectively arranged on opposite sides of a movable band, and each chamber is provided with an exhaust valve which is kept closed when any of the wind-admitting orifices of the corresponding chamber is opened. The shutters when closed are kept closed (so long as the swell pedal is right down) by an electric circuit which arranges for wind to be admitted to an orifice and so to the receiving chamber of the motor. Examination of the pedal diagram of Fig. 3 will show how the contacts are operated by the organist's foot. Fig. 2 only shows one valve controlled by one electric magnet but, of course, there is a separate valve and magnet for each contact made by the pedal, and these valves in turn control the admission of wind to the various orifices above mentioned. The contacts (in Fig. 3) are arranged in two groups, one set being mounted on one side of the movable conductor bar and the other set on the other side of this bar. A link attached to the pedal at one end is supported at its other end between two springs: these springs urge the pedal to a neutral position and so move the bar to a position between (and so out of contact with) all the contacts. The contacts are arranged at different distances from the bar when the latter is in its neutral position. As the bar is moved in either one or the other direction the circuits through the respective groups of contacts are successfully and cumulatively closed. The position of each contact is adjustable by means of the screws provided for the purpose, thus varying the distance through which the bar, after contacting one blade, must move before contacting the next in order. The regulation of these movements and relative distances makes all the difference to the effectiveness of the mechanism, as can well be realised.

The shutters of most modern swell boxes are arranged in vertical formation so as not to be affected by gravity in their movement, but the earlier boxes had horizontal shutters which opened and closed in similar fashion to the Venetian blind of Victorian days. Shutters can be placed either in front or on top or on two sides of the box as the builder may determine. Mr. Compton has in many of his organs utilised a stone or brick chamber (as part of the building) for the housing of his swell boxes and arranged the shutters to open at the back so that the sound may be reflected into the auditorium from the back wall of the building. Most builders construct their swell boxes of wood, and various methods have been employed to make the panels as sound-proof as possible. The interior of the box is usually lined with stout brown paper or some non-absorbent material such as cement. This helps to reflect the sound from the box into the building. For the purpose of making the box sound-proof I can strongly recommend filling the interstice between two thicknesses of wood with sand, and it is hardly necessary to add that the shutters must be most carefully fitted so as to allow no possibility of outside air gaining admittance. The number of shutters and their thickness, width and length are matters which the organ builder has to decide for himself in reference to the size of the box, the total volume contents of the stops enclosed therein, the situation of the organ, and the acoustics of the building. There is a definite limit to the width of a shutter and it should not be less than 7 in. wide nor more than 9 in. for a normal size of box: each shutter should turn on a brass cup or plate for smooth working. The tendency of wood to warp and twist makes it desirable to make the shutters of strips of wood glued together with the grain running in reverse directions. Sheet metal has been used by the Austin Organ Company (U.S.A.) for their shutters, mounted on wooden frames. In order to ensure a tight closure the edges of the shutters are usually lined with felt and sometimes wooden fillets are fitted at the joints as an extra precaution. Hope-Jones employed what he called a "sound trap," which took the form of a series of grooves cut in the bevelled edge of the shutters. The actual thickness of the walls of the box depends, or should depend, on the total power of the stops enclosed: it is not desirable to convert the box into what Audsley termed a "tone-annihilating chamber," so that common-sense would dictate the principle of thickness of walls in relation to volume of sound to be released and suppressed—lightly winded choir or echo stops requiring a thinner box than heavily winded swell or solo stops.

CHAPTER XIV

Soundboards and Chests

HAVING viewed the Organ from the console point of view and followed the mechanism from key and drawstop to soundboard and chest, let us now go to these latter parts of our instrument and look at the structure and mechanism at this end of the chain.

The two terms "soundboard" and "chest" are usually regarded as mutually interchangeable, but I prefer to make a difference between them, reserving the name "soundboard" to the (a) old type of barred chest, with or without sliders, and (b) any type of chest that has expansion chambers fitted between the pallet holes and the pipe-feet. The question arises as to whether it is necessary to add the chamber referred to and why it should be added at all. Originally, the chamber took the form of a series of long and rather narrow grooves as shown in Fig. 35 which gives an upside down picture of a barred slider soundboard in section. It was possible by this arrangement to plant several ranks of pipes on one soundboard: the soundboard shown in Fig. 35 is planned for three stops as can be seen from the three sliders. The grooves are separated by bars, and the pallets are placed over and along them, as shown. The sliders are fitted between the table and the upperboard (not shown) and the pipe-feet stand on the upperboard, being held in position by the rackboard (as shown in Fig. 36). Now it so happens that the groove which was originally designed to enable the builder to place more than one stop of pipes on one soundboard (see Fig. 36) introduces a certain aerodynamic effect on the pressure-wind as it flows past the opening pallet into the pipe-foot. If the pipe is made to stand on the upperboard so that wind passing the pallet is able to gain admission to the pipe-foot through a channel (whatever the length of the channel or conduit), the pressure of the wind is not uniform in its flow. The opening of the pallet produces vortices which oppose the flow of wind, and there is an initial backward flow due to a shock wave which must precede the progressive flow of wind to the pipe. In order to overcome this it is necessary either to introduce an expansion chamber of suitable capacity or else to arrange the fitting of the pallet so that it opens **with** the wind instead of against it (as in Mr. H. W. Homer's chest shown in Plate XV). The groove of the old-fashioned slider soundboard, if made to the right dimensions (as in Schulze's, Father Willis's and T. C. Lewis's soundboards), provided the requisite expansion chamber. And, of course, it is easily possible to fit expansion chambers to a barless chest, if desired, although the expansion chambers must be almost inconveniently large if they are to produce the desired effect. But is it necessary to go to this extra trouble? This is the question that so many organ builders are asking. Mr. G. Donald Harrison is convinced that the expansion chamber is entirely superfluous. Up to the time when organ building was stopped by the second world war, Messrs. Harrison and Harrison were using the barred soundboard in all their organs, so far as I am aware; but the majority of builders in this country appear to be using the pitman chest in one form or another, since it offers certain very distinct advantages in connection with modern electric systems. The expansion chamber can be fitted to the pitman chest as I have indicated in the sketch of this chest later in this chapter. I find it very difficult to persuade organ builders in this and other countries to see any real advantage in the expansion chamber, so that it does look as if it will die a natural death before many years have elapsed. I shall no doubt be considered a die-hard in voicing the views expressed in this paragraph when I say that I infinitely prefer the tonal result of a diapason chorus consisting of pipes voiced on the old type of barred and grooved soundboard. The difference between diapason pipes standing on a barless and a barred chest may not be obvious if the pipes are made to speak singly or in a detached chord or sequence

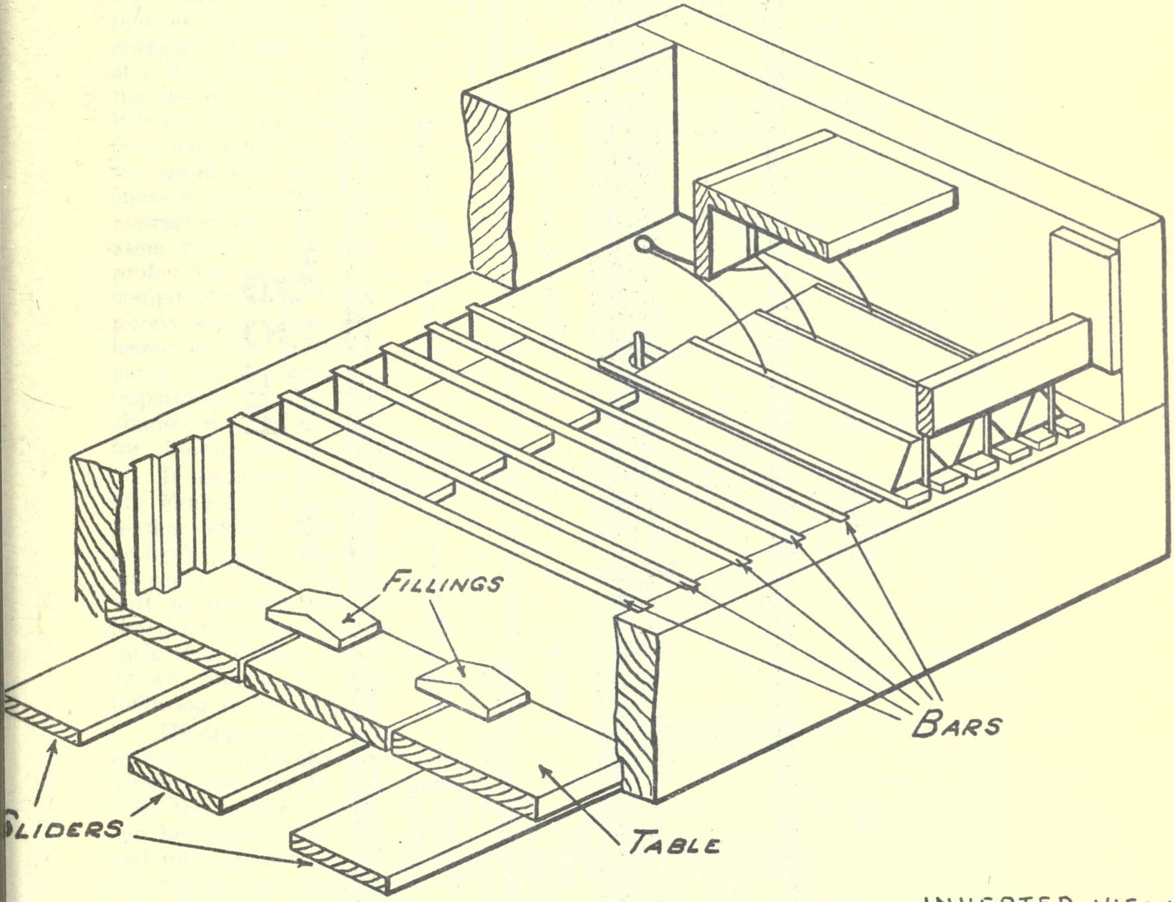
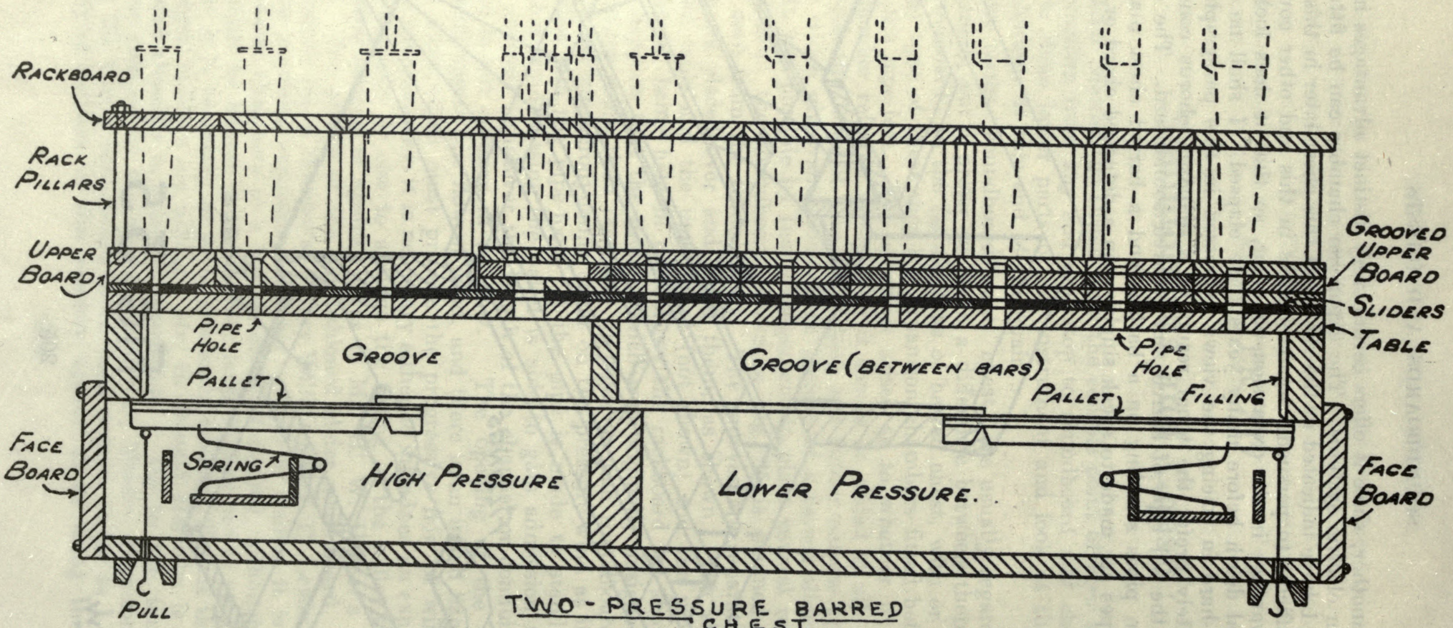


FIG. 35

REPRODUCED BY PERMISSION OF MESSRS SAMPSON LOW.

INVERTED VIEW OF BARRED CHEST.


RACKBOARD
RACK PILLARS
UPPER BOARD
PIPE HOLE
GROOVE
PALLET
FACE BOARD
SPRING
HIGH PRESSURE
PULL
GROOVE (BETWEEN BARS)
LOWER PRESSURE.
PALLET
PIPE HOLE
FILLING
GROOVED UPPER BOARD
SLIDERS
TABLE
FACE BOARD

TWO-PRESSURE BARRED CHEST.

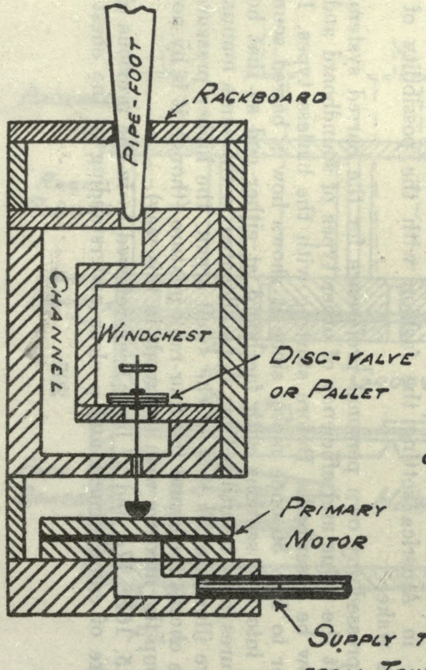
FIG. 36

of chords. It is only observable if **two different players of recognised skill are asked to play a few bars of music and a musician is asked to report on the effect of each rendering.** The same musical excerpt is repeated on the same set of pipes placed first on a barless and then on a barred chest. What precisely will be the difference? There will be a distinct change of formant colouring in the two instances owing to the fact that (a) the pipes are differently blown by the respective chests, and (b) the player by the manner in which he manipulates the keys (and the pallets) in their time-relation when passing from note to note and chord to chord will energise a formant colouring of his own. These differing formant colourings are not noticeable when music is played on diapasons (and other types of organ stop besides) blown by barless chests owing to the shock-wave characteristic of the wind supply above referred to which considerably reduces the energy of the formants. The reason for this is that the formant is energised in the first instance by the shock of the wind against the upper lip of a flue pipe, as I have proved. That initial shock of wind is attenuated by the motion of the pallet in the barless chest, and when the pressure is restored it is too late to launch the full formant. In the case of reed pipes this condition does not apply, so that the barless chest is quite suitable for reeds. Although the speed with which the pallet is able to supply wind to the pipe from a pitman chest is much greater than from an ordinary type of barless chest, the barless characteristic is not eliminated: the restoring time is brought nearer to the attenuation point in the flow of wind between pallet and pipe, but the formant is profoundly affected by the change of flow. I make these statements with a complete sense of responsibility knowing them to be true and unassailable on purely scientific grounds. In the rendering of polyphonic music the formant losses are not so serious, since the chief desideratum is clarity and definition of parts, and the actual colouring of the tonal ingredients employed is of secondary importance. In the accompaniment of Divine Service, however, the tone-colouring characteristic is of supreme importance, and I am all for the barred soundboard for church organs, especially for the great diapson chorus.

It was shortly after I had written the foregoing that I received a letter from Mr. Ernest M. Skinner, of America, who complained of the new process of tanning leather which militated against its use in the pitman chest, since it would probably need replacement in about 18 years. Consequently, he has developed an action, both stop and key, that makes the slider chest respond as fast and with as much sympathetic response as the pitman. If this means a return to the time-honoured barred and slider soundboard for the tenor C portion of each rank of a division (the basses being planted off), we shall have at least one well known builder in America setting the fashion with the possibility of others following in his wake.

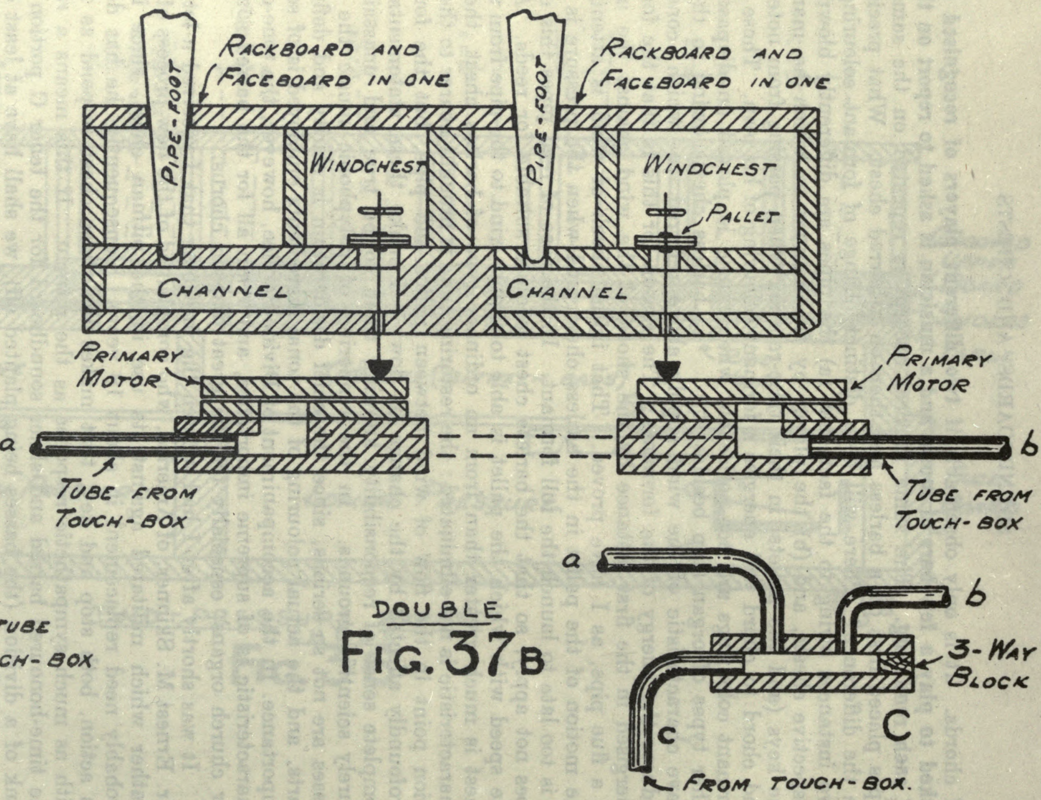
Having expressed my own personal preference for the barred system, I am willing to admit the value and efficiency of other types of soundboard and chest. These must now be described. Before starting with the barless types, I would refer the reader to Fig. 36 once more, since it shows how a barred soundboard can be divided into two sections with faceboard at either end so that both low and high pressures may be utilised for stops allocated to the same manual. The soundboard here illustrated is that of the swell organ, the higher pressure being reserved for the chorus reeds and the four-rank mixture (though it is by no means essential to group the mixture with the reeds in this way).

Figs. 14, 15, 16B, 17A and 27 have been referred to in the previous chapter, but for the sake of completeness and a clear understanding of the chest action


PIPE-FOOT
RACKBOARD
CHANNEL
WINDCHEST
DISC-VALVE OR PALLET
PRIMARY MOTOR
SUPPLY TUBE FROM TOUCH-BOX

SINGLE

FIG. 37A


PIPE-FOOT
RACKBOARD AND FACEBOARD IN ONE
WINDCHEST
CHANNEL
PIPE-FOOT
RACKBOARD AND FACEBOARD IN ONE
WINDCHEST
PALLET
CHANNEL
PRIMARY MOTOR
PRIMARY MOTOR
a
TUBE FROM TOUCH-BOX
b
TUBE FROM TOUCH-BOX
a
b
3-WAY BLOCK
c
C
FROM TOUCH-BOX.

DOUBLE

FIG. 37B

which operates the pallets in each case I will give a brief description of them here.

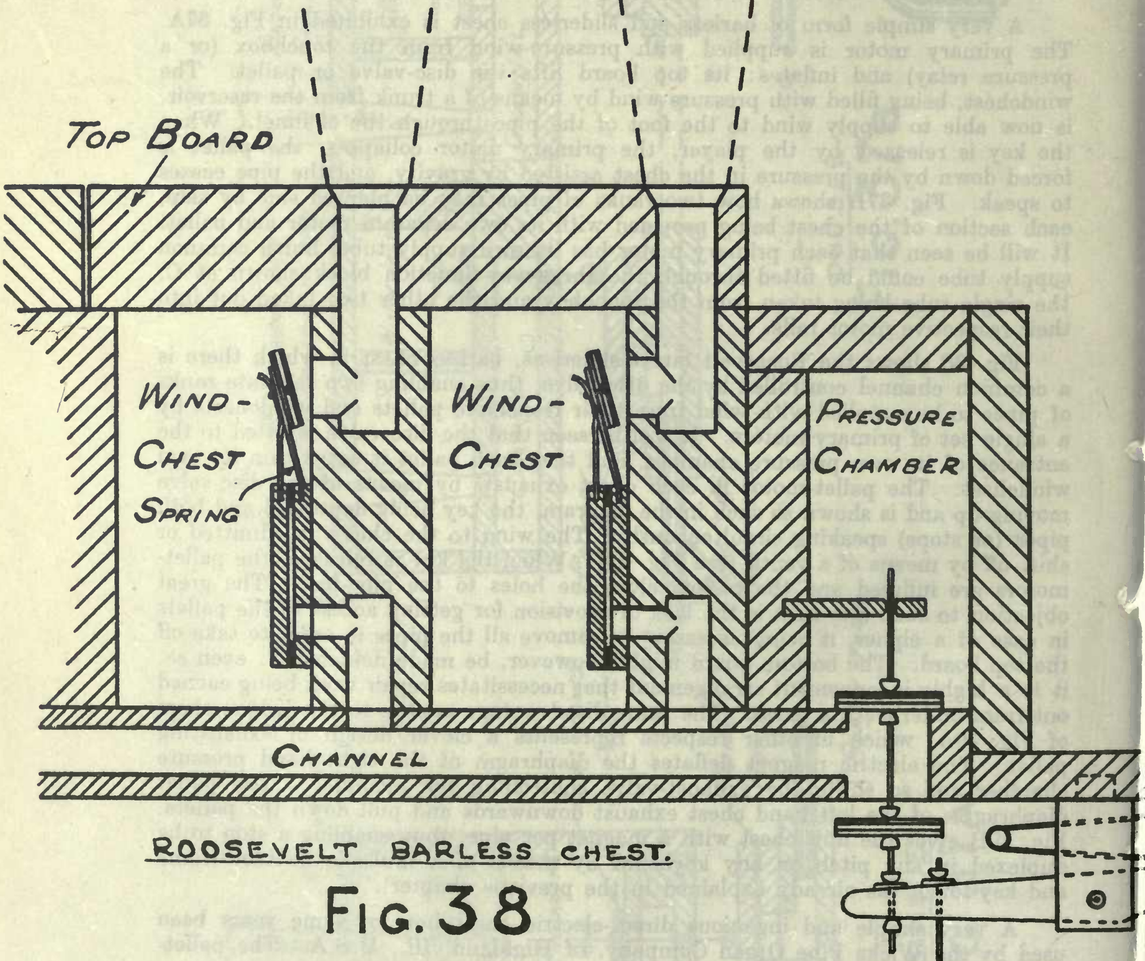
Fig. 14 shows a barred and slider soundboard fitted with a relief motor, the action of which I have already explained. Fig. 15 illustrates how the barred and slider soundboard pallet was controlled by a pneumatic lever action, while Fig. 16B reintroduces the relief motor now functioning in a new rôle as an exhausting lever directly pulling down the pallet. Here the chest need not have any bars or grooves, and there are numerous examples of this type in English organs. The same applies to the chest of Fig. 17A, which has an exhaust pneumatic action. Here all three motors exhaust in sequence, **a**, **b** and **c** in that order, the first two motors actuating their respective disc-valves, and the third motor pulling down the pallet. In Fig. 27 we have the chest of Fig. 16B with a relay motor exhausting through the port-hole opened by an electric magnet armature: the pallet motor thus collapses through the exhaust-hole opened for it by the disc-valve.

A very simple form of barless and sliderless chest is exhibited in Fig. 37A. The primary motor is supplied with pressure-wind from the touchbox (or a pressure relay) and inflates: its top board lifts the disc-valve or pallet. The windchest, being filled with pressure-wind by means of a trunk from the reservoir, is now able to supply wind to the foot of the pipe through the channel. When the key is released by the player, the primary motor collapses, the pallet is forced down by the pressure in the chest assisted by gravity, and the pipe ceases to speak. Fig. 37B shows how two ranks of pipes may be planted side by side, each section of the chest being provided with its own separate motor and pallet. It will be seen that each primary motor has its own supply tube, but a common supply tube could be fitted through the three-way junction block shown at C, the single tube being taken from the touchbox and the other two taken out into their respective motor rails.

Fig. 38 shows the Roosevelt latest sliderless, barless chest in which there is a common channel controlled by the disc-valve, thus enabling two separate ranks of pipes to be supplied with wind from their respective pallets and windchests by a single set of primary motors. It will be seen that the disc-valve is fitted to the entrance of its own pressure chamber, and that each pallet is set within its own windchest. The pallet-motor in each chest exhausts by means of the disc-valve moving up and is shown as such in the diagram, the key being depressed and both pipes (or stops) speaking simultaneously. The wind to the chests is admitted or shut off by means of a ventil (see Fig. 25). When the key is released, the pallet-motors are inflated and the pallets close the holes to the pipe-feet. The great objection to such a system is the lack of provision for getting access to the pallets in case of a cipher, it being necessary to remove all the pipes in order to take off the top board. The bottom board might, however, be made detachable: even so, it is a highly inconvenient arrangement that necessitates repair work being carried out from underneath a chest. The same disadvantage applies to the Kilgen chest of Fig. 39A, which in other respects represents a clever design of exhausting pallet. The electric magnet deflates the diaphragm of the right hand pressure chamber and so shifts the exhaust-valve controlling the channel. The pallet diaphragms of the left hand chest exhaust downwards and pull down the pallets. Fig. 39B gives the unit chest with a magnet per pipe, thus enabling a stop to be duplexed in any pitch on any keyboard by means of a multiple contact frame and key-touch (as already explained in the previous chapter).

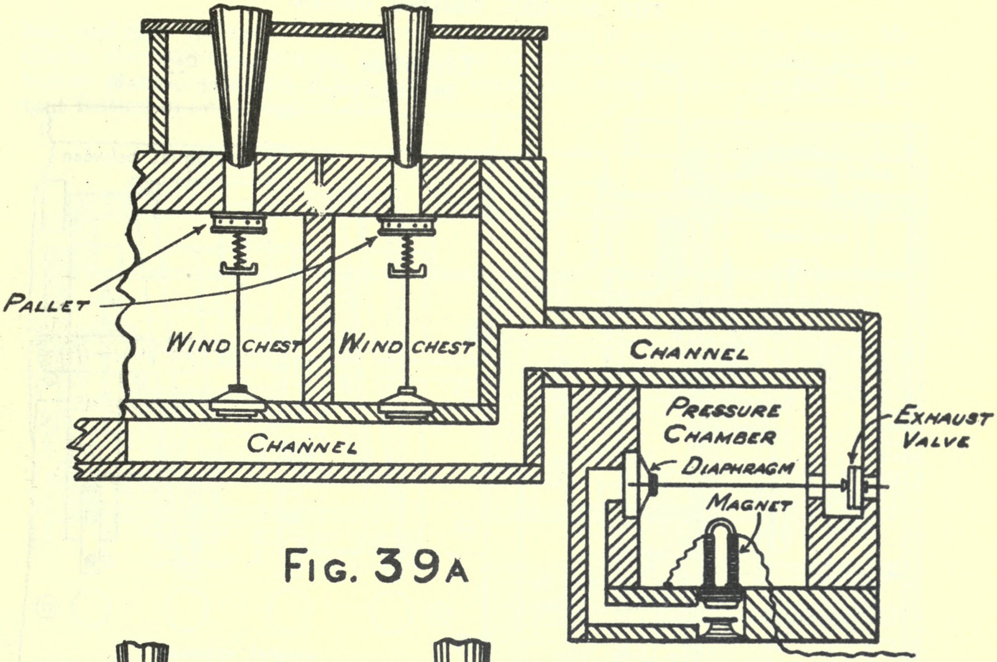
A very simple and ingenious direct-electric chest has for some years been used by the Wicks Pipe Organ Company, of Highland, Ill., U.S.A. The pallet-valve controlling pressure-wind to the pipe-foot is directly connected to the moving armature of a core magnet which is energised by the depression of the key in the usual manner. The only disadvantage of the system is the amount of current consumed when a large number of these magnets are operated simultaneously. There is also a tendency for flue pipes to speak in advance of reed pipes in staccato playing, though this fault, if recognised by the builder, can be overcome.

Plate XII shows a windchest for diapason fronts employed by Mr. C. H. Clarke. The pallet motors with their supply and exhaust valves are carried by a removable bar, while the magnets are mounted on a removable baseboard and offset so as to clear the valve stems. Exhaust channels lead to pneumatic purses in the removable board at the rear. The pallets are placed between the pallet motors to allow access to the pallet springs. The pallets, it will be observed, are



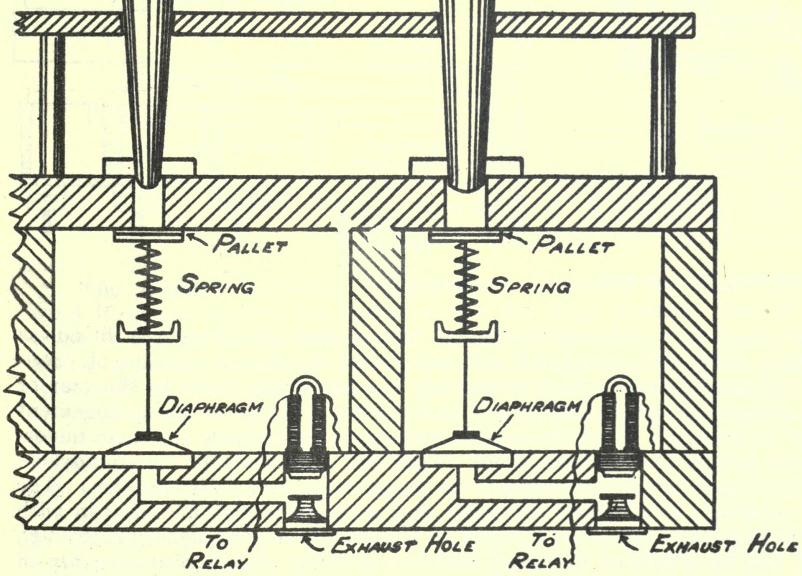
ROOSEVELT BARLESS CHEST.

FIG. 38



PALLET
WIND CHEST
WIND CHEST
CHANNEL
CHANNEL
PRESSURE CHAMBER
EXHAUST VALVE
DIAPHRAGM
MAGNET

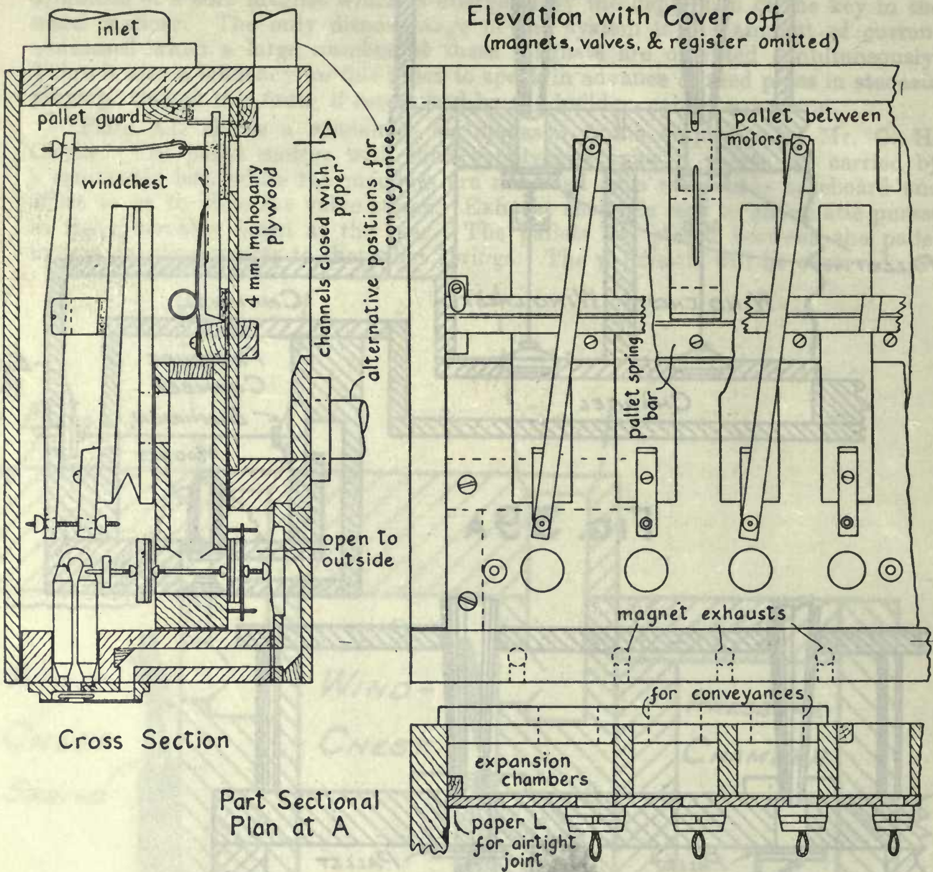
FIG. 39A



PALLET
PALLET
SPRING
SPRING
DIAPHRAGM
DIAPHRAGM
TO RELAY
EXHAUST HOLE
TO RELAY
EXHAUST HOLE

UNIT CHEST (KILGEN TYPE)

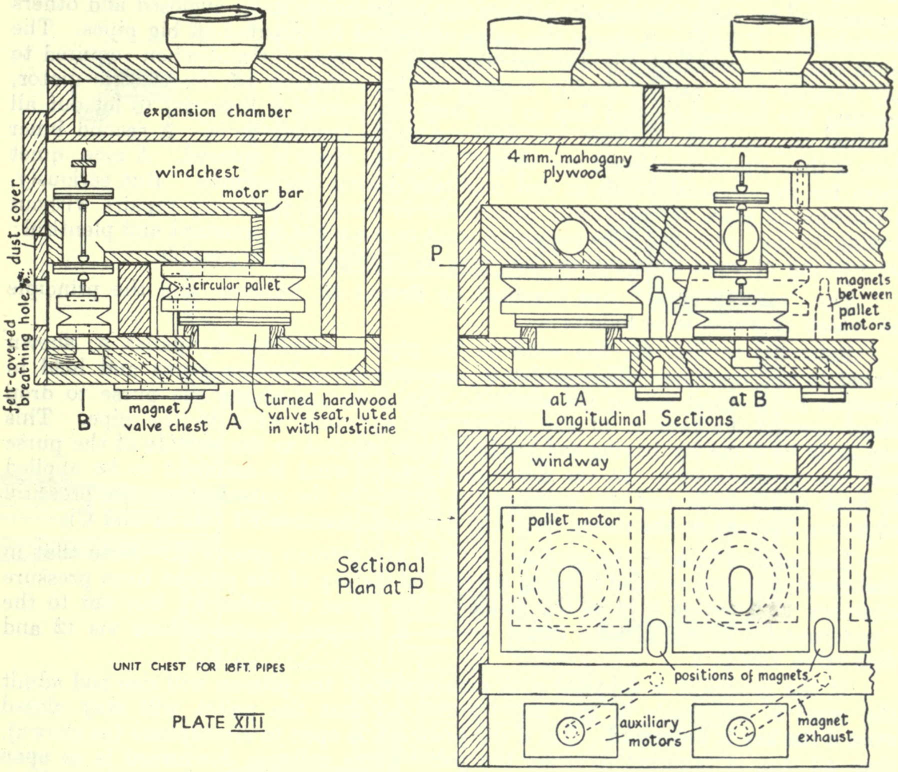
FIG. 39B


inlet
pallet guard
windchest
A
4 mm. mahogany plywood
channels closed with paper
alternative positions for conveyances
open to outside
Cross Section
Elevation with Cover off
(magnets, valves, & register omitted)
pallet between motors
pallet spring bar
magnet exhausts
for conveyances
expansion chambers
paper L for airtight joint
Part Sectional Plan at A

UNIT CHEST FOR FRONT PIPES

PLATE XII

opened and closed by means of backfalls. Expansion chambers are fitted as shown. The front pipes are supplied with wind from the chest by means of "conveyances" (small trunks or tubes) connecting the front pipe block to the rear or top (as convenient) of the channel of the chest. Plate XIII gives the arrangement for a 16 ft. unit chest. Here inverted motors carry disc-pallets on their undersides. These pallets rest by their own weight on valve-seats in the removable bottom of the chest which also carries the magnets and auxiliary motors. The removable valve-seat is a turned hardwood ring with vertical grain, luted in with plasticine, thus giving free access of wind all around. The wind channels through the bottom and back wall of the chest lead to expansion chambers on the top of the chest, and the back wall channels are skewed as required to reach the pipe positions. The magnets are placed between the motors to economise space, and the exhaust channels to the auxiliary motors are skewed as shown in the plan. The pallet motors with their supply and exhaust valves are carried by a removable bar, and light springs hold the valves up when there is no wind in the chest. Mr. Clarke claims that access for adjustments or repairs is readily available in these barless chests by means of the various removable cover-boards—a highly important feature in any design of chest.


expansion chamber
windchest
motor bar
dust cover
felt-covered breathing hole
circular pallet
B
magnet
valve chest
A
turned hardwood valve seat, luted in with plasticine
4 mm. mahogany plywood
P
magnets between pallet motors
at A
at B
Longitudinal Sections
windway
pallet motor
Sectional Plan at P
positions of magnets
auxiliary motors
magnet exhaust

UNIT CHEST FOR 16FT. PIPES

PLATE XIII

The Austin "universal windchest" is illustrated in Plate IX. Pressure-wind from the electric fan blower enters the large chamber through the supply trunk A of Fig. 2, the flow of wind being regulated by a valve (as shown). The actual pressure of wind is determined by the degree of tension applied by the springs B to the inside surface of the reservoir top board C against the pressure of wind outside. Wind is admitted to the pipes by means of valves which open downward in a hinge-like movement. Fig. 1 shows an enlarged view of the key mechanism. The armature 2 is drawn to the energised magnet 1 as soon as the key is depressed. The purse or pouch 3 exhausts to the right and pulls with it the exhaust-valve 4. Motor 5 then exhausts through the channel thus opened to outside air and draws the trace 6 to the left. The upright trigger-bar describes a mild arc movement, pivoting at point 8, but it achieves nothing because the stop has not been drawn. In order that the trigger may be able to lever the pipe-valve down as shown at E in Fig. 2, the stop-control mechanism 9 must be shifted to the position indicated by the dotted line. The wire 7 is now able to come into play, since it can swing over the stop-control plate 9 and bring the pipe-valve down. In Fig. 2 two trace-rods are shown connected to a centre block and operated by a pneumatic motor at either end of the chest. This arrangement provides for the key action of two manuals each of which respectively controls the stops represented by the pipes standing above the pallet-holes, some enclosed and others unenclosed. F in Fig. 2 shows the valve employed for planted-off big pipes. The chest can be entered by the door on the right. Repairs, if and when required to any interior part, can be readily carried out by switching off the electric motor, opening the leather-covered flap in the door (by poking it inwards) to let out all residual air, opening the door and walking inside the vestibule. A second inner door is then similarly treated and opened, and the chest is entered. A nice, quiet room for the organist to sit in and meditate during the sermon! But seriously, a convenient place for the same gentleman to execute necessary repairs without having to don overalls. The supply of wind to the pipes is constant and plentiful: no robbing of wind from this or that stop by another stop is possible.

The "pitman chest" was invented by Ernest M. Skinner, and the principle on which it works is as follows:—

Referring to Fig. 40, the wind to the pipe is admitted by pallet A, shown closed in the drawing. This pallet is mounted on a leather purse and held in position by a spiral spring (as shown). The object is to get the purse to drop down against the tension of the spring and so admit wind to the pipe. This can only be done by having the pressure-wind applied to the **outside** of the purse and not to the inside. In the drawing, pressure-wind is assumed to be applied to both the outside and the inside of the purse—to the outside from the pressure chamber F3, and to the inside from the pressure chamber F1 (via t1 and C).

Let us now look at the pitman (pt) and the pitman groove K. Note that in the drawing pressure-wind is being applied to the top of the pitman from pressure chamber F1 (just as it is to the inside of the purse of pallet A), but **not** to the "underneath" of the pitman (since groove K is open to atmosphere via t2 and disc-valve D2).

If the groove K is supplied with pressure-wind the pitman will rise and admit the wind to the inside of the pallet-purse, so that the pallet will stay closed **even if the key is depressed.** But if the groove K is open to atmosphere (as shown), then all that is required to make the pallet-purse collapse downward is to **open groove C to atmosphere. Then,** the pressure-wind from chamber F3 will force the pallet and purse down and the pipe will speak.

To open groove C to atmosphere it is only necessary to get the pneumatic motor H1 to collapse and lift disc-valve D1. The player by pressing his key excites the magnet G1 so that the armature valve B1 is drawn up, thus opening the exhaust-hole to atmosphere. Similarly, if the armature valve B2 of the draw-stop box is released, it will enable wind to flow from pressure chamber F2 to the pneumatic motor H2 which in turn will admit wind through the disc-valve D2 to t2 and K.

To recapitulate: the situation shown in the drawing is (1) drawstop **on,** but (2) no key depressed; therefore no sound. Press the key, and motor H1 closes up and exhausts groove C. Pressure-wind is now applied to the outside only of pallet-purse, forces the pallet open and blows the pipe. Release the key, and pressure is applied to both the outside and the inside of the pallet-purse; the pallet closes and the pipe is silent. Push the stop in, and the pallet remains closed, since the pitman blows up and closes C, but admits wind to the inside of

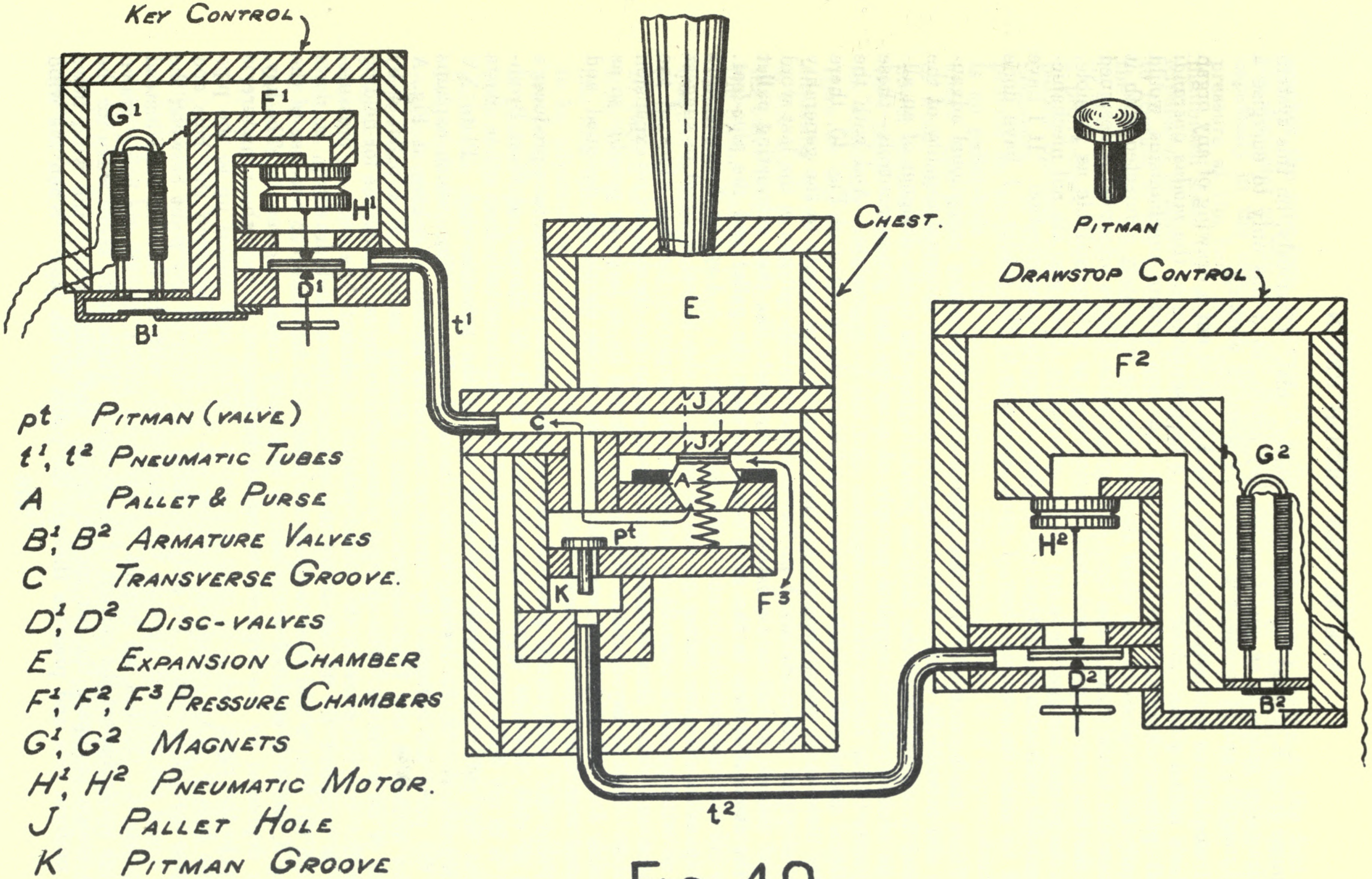

Key Control
G¹
F¹
H¹
D¹
B¹
t¹
Chest.
E
J
J
C
A
pt
K
F³
t²
Pitman
Drawstop Control
F²
G²
H²
D²
B²
pt Pitman (valve)
t¹, t² Pneumatic Tubes
A Pallet & Purse
B¹, B² Armature Valves
C Transverse Groove.
D¹, D² Disc-valves
E Expansion Chamber
F¹, F², F³ Pressure Chambers
G¹, G² Magnets
H¹, H² Pneumatic Motor.
J Pallet Hole
K Pitman Groove

Fig. 40

Theoretical plan of a pitman chest.

the purse from K instead! (Diabolically clever, this). Obviously, on this system the drawstop action is as smart as the key action, as it has only to energise a small magnet; and of course it is absolutely silent in working.

I would have it clearly understood that Fig. 40 is **not** a drawing of any organ builder's actual pitman chest—it is solely a representation of the *modus operandi* of all pitman chest systems. The key and stop control mechanisms would normally be contained in the chest itself or else be intimately connected with it without the tubes t1, t2. The form of diagram which I have presented is designed to make the various parts and their relationships as understandable as possible, since the pitman mechanism is not readily grasped by those who are not mechanically-minded without a more than usual effort of mental concentration. If I have failed to make its working clear, I must apologise to the reader. I have done my best.

There can be no doubt that the pitman chest offers many exceptional advantages and attractions to the modern organ builder. The abnormal rapidity of the key and drawstop action, the facilities which it presents to the designer of an all-electric console with a complete panoply of couplers and piston controls—these are points in its favour that no engineer can fail to appreciate. And with the expansion chamber E, which I have embodied in the drawing of Fig. 40, there can be little cause for uneasiness in the matter of wind supply to the generality of organ pipes. Nevertheless, I am not satisfied that the pitman is the last word in chest design, for all its cleverness. **I do not quite like that exhausting pallet and the channel-system in the upperboard between the pallet and the pipe-foot.** Eddy currents are bound to occur in the pallet-hole (J . . . J in the drawing), and the expansion chamber cannot get rid of them. I should feel inclined to suggest that no wind pressure over 2½ in. ought to be employed for flue pipes of the diapason and string class from a pitman chest, expansion chamber or no expansion chamber. That is my opinion. The pallets should be as large as possible so as to make J . . . J as wide as possible, and the purse should be designed and operated with this object in view.

From the aerodynamic point of view and therefore from the tone-producer's point of view, the new type of chest invented by H. W. Homer, of West Bromwich, is in my opinion *facile princeps*. It differs fundamentally from other chests in that the pallet opens **with** instead of against the pressure-wind. Plate XV is a reproduction of the drawing in the files of the Patent Office, which explains why the parts are indicated by numbers instead of letters. Looking at Fig. A we see housed in box 1 an electro-magnet 3 directly coupled to a pallet 4 by means of an armature. The spring 5 is tensioned to the correct degree for holding the pallet and armature in the closed position as shown. As soon as pressure-wind is supplied to the chest by the electric blower and drawstop, it flows through the inlet 2 and tries to open the pallet. It fails to do so because of the spring 5, which is adjusted to the correct tension by means of screw 6. The key, when depressed by the organist, energises the magnet so that the armature is drawn to the right and pulls open the pallet. Wind now passes up to the pipe via the hole 8. (An expansion chamber can be inserted between this hole and the pipe-foot, if desired). No eddy currents can form at any point between the inlet 2 and the outlet 8, because the pallet opens **with** the flow of wind instead of against it. (Eddies are formed, as everyone knows, by an oar being drawn through water **against** the current of the stream). There is no shock wave for the same reason (compare the oar motion again), and consequently the wind flows at a uniform rate and pressure through the pallet to the pipe. When the wind reaches the pipe-foot, however, it suffers a slight check owing to the fact that the diameter of the foot-hole is smaller than that of the wide end of the foot, especially in the case of a flue pipe; but if the pipe is voiced to speak on the pressure at the foot, any trouble due to the formation of the foot itself will be minimised since the wind is injected at a uniform pressure **up to this point.** An expansion chamber would provide a further safeguard against possible loss (due to friction at the foot-hole and flue) of pressure at the moment of articulation in the case of a diapason pipe, but it would not have to be so large as that required by any other type of chest. String-toned pipes will speak their full note with a promptness unknown to voicers accustomed to the barless chest fitted with pallets opening against pressure. For these pipes no intermediate chamber is necessary. It should be noted in addition that the box 1 is sufficiently large to provide an air-pressure chamber between the pallet and the outlet hole 8. **There is no pallet-hole** in the accepted sense. This arrangement is of supreme importance. The pallet functions with complete silence: there is no sharp cutting off of wind, no shearing of the wind by the pallet-stroke, as in **all** other chests. The power required to start the pallet moving is quite small, so that its response is very rapid. There is nothing to prevent a much larger size of pallet being used for supplying wind to large pipes if the arrangement shown in Fig. B is employed. Here we see the same magnet and armature controlled by the spring 5 (and the adjusting screw 6), but in addition there is a pneumatic motor 10 (whose diameter is the same as that of the inlet hole 2) which holds the pallet in position over the inlet hole 2 by means of the connecting rod 9 attached to the top board of the motor (inside) at one end and the pallet at the other end. (The connecting rod slides smoothly through a bushed hole in the side of the chamber 1.) When the magnet is energised and the armature pushes the pallet away from the inlet hole to the right, the pallet has to overcome the resistance of the pneumatic motor 10 (which is being forced leftwards by the pressure-wind in the main chest). Now look at the two small holes 11 and 13 by which the air in chamber 1 alone can find admittance to the motor. The set-screw 12 enables the size of hole 11 to be adjusted to a nicety, while the leather flap 14 acts as a non-return valve preventing wind from passing out again from within the motor. When the pallet is pushed open by the armature it is able quite easily to move the top board (10) of the motor to the right and is, in fact, in balance with it, so that the pallet can open with the minimum of delay and the pipe, however large, gets its full wind at once. Thus; even when staccato notes are played, the pipe can respond without hesitation with mature speech—an important point. Similarly, when the key is released and the electric current cut off: the pipe should not be deprived of its wind supply at the same rate of cut-off as the electric current, nor on the other hand should it be allowed to "hang on its note" too long after release of the key. The optimum time-constant can be effected by adjustment of the screw 12 which controls the exhaust-time of the motor and therefore the return-time of the pallet. The air in the motor **must** exhaust through the orifice 11, since the orifice 13 is closed by the non-return valve.

It will be observed that this is a direct-electric action chest, and that it is subject to the same disadvantage common to all direct-electric actions, namely a high current consumption, though I think the inventor would be willing to claim that his magnets need not take more than 100 milliamperes each. Even if the number of stops provided for by this system of wind supply were limited to half a dozen, the stops to be so supplied could be wisely chosen by the tonal architect as likely to derive the greatest benefit from the treatment, while the remainder could be planted on any other type or types of chest or soundboard desired. Alternatively, the Homer chest could be fitted with a pneumatic auxiliary action in place of the electro-magnet shown in the drawing, the electrical part of the key mechanism being confined to the primary exhaust movement.

One final warning seems called for in connection with all direct-electric actions in which the assistance of pneumatic motors is dispensed with. Electric current, as every electrical engineer knows, takes time to build up in a highly inductive circuit such as the wound magnet. In order to reduce the time-constant to a minimum it is desirable to employ as few magnets as possible per note in the action chain from key to pipe. The key mechanism should therefore be designed to this end if a quick and reliable action is to be guaranteed.

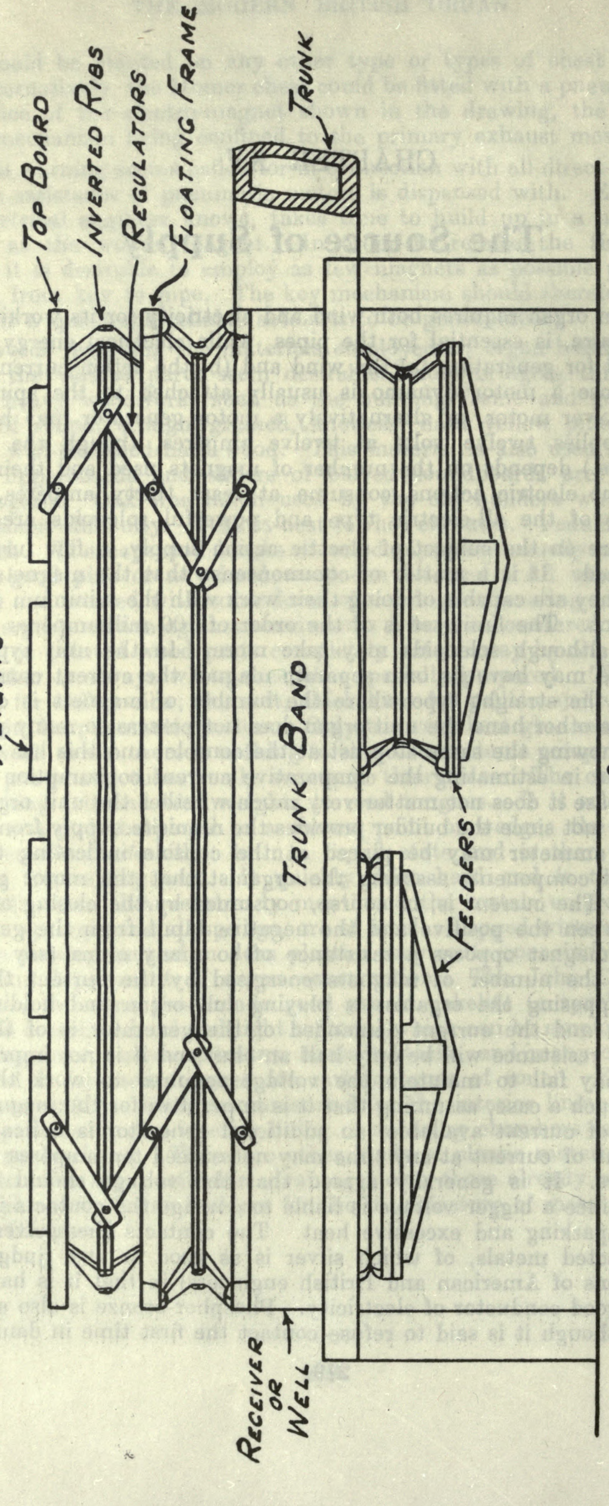
A few words regarding the materials employed by organ builders in the construction of the various parts seem desirable before bringing this chapter to a close. The heavy woodwork, such as the building frame and general supports are usually of sound, straight-grained, knotless, hard yellow pine, or any other reliable and well-seasoned hard wood. This material is also used for wood pipes. The tables, upperboards and sliders of barred soundboards are made of "bay wood" mahogany. Oak was much used by the old builders who were able to obtain it without difficulty. Teak is best for hot climates. Pedalboards are often made of birch. The caps and blocks of wood pipes are usually of mahogany or oak, though good pine or any hard wood can be used. All wood parts should be varnished and treated with some form of worm-proof coating. Ordinary paint is useless as a preventative against woodworm: I have encountered many examples of varnished or painted wood parts completely eaten away by the worm. Organ builders' leather is always white sheepskin specially prepared. The "stretched" kind is used for bellow-ribs; the soft, thick kind for pallets and valves; and the finest splitskin for pneumatic motors. Only the very best glue must be employed for leather work, while there is nothing to beat Chatterton's compound for making the ends of pneumatic tubes really secure in their holes. The compound is also used for sticking felt and lead weights to reed tongues. It is sold in sticks and should have one end sharpened to a narrow point or wedge: the pointed end is held over a candle flame till it is in a liquid state and is then applied to the required part like sealing wax. It quickly dries hard and is therefore a very convenient adhesive. I have already mentioned the metals employed in electric work. Pallet springs, and all springs, are of steel. Tapped wires are of phosphor bronze. The development of modern plastics may quite conceivably revolutionise the engineering department of organ construction. The John Compton Organ Company have for some time made good use of bakelite (a synthetic composed of phenol and cresol), a hard and light material which can be employed for magnet bases, coupling bars, valves, pitmans, contact blocks, and many other parts. (I can commend it for reed tongues for certain types of tone). Everite (a form of asbestos cement) has been recommended for the interior lining of swell boxes and more especially for the interior lining of silencing chambers in which electric fan blowers are enclosed. There are other kinds of plastic material, but they do not appear to offer any particular advantages over those already mentioned. The material employed by organ builders for the manufacture of metal pipes has been described in Chapter I.

CHAPTER XV

The Source of Supply

THE modern organ requires both wind and electricity for its working. Wind, under pressure, is essential for the pipes, while electrical energy or E.M.F. is employed for generating (a) the wind and (b) the action current. For the latter purpose a motor dynamo is usually attached to the spindle of the rotary or fan blower motor, or alternatively a motor generator may be installed. This usually supplies twelve volts at twelve ampéres, though the amount of current (in amps.) depends on the number of magnets used and their total consumption. Some electric actions consume at least thirty ampéres, especially if the console is of the all-electric type and powerful solenoids are employed.

While we are on the subject of electric action supply, a few further details may be mentioned. It is a matter of commonsense that the magnets should be so wound that they are capable of doing their work with the minimum expenditure of electric current. The limit set is of the order of 100 milliampéres (or a tenth of an ampére), although solenoids may take more. In the unit type of organ where every pipe may have its own separate magnet the current consumption is greater than in the straight type where the number of magnets is considerably reduced. On the other hand the unit organ does not possess so many pipes as the straight organ showing the same stop-list at the console, and this has to be taken into consideration in estimating the comparative current consumption of the two types. In any case it does not matter very much whether the unit organ requires more current or not since the builder provides the requisite supply from the motor generator. An ammeter may be placed at the console indicating the current passed—a useful component, assuring the organist that the motor generator is doing its duty. The current is, of course, consumed by the closing of a number of circuits—between the positive and the negative input from the generator the winding of the magnet opposes a resistance of so many ohms (say 100 ohms), and the greater the number of magnets energised by the current the less the resistance. Supposing the organist is playing full organ and holding a final sustained chord, and the current demanded of the generator is of the order of 20 ampéres; the resistance will be only half an ohm and it is not improbable that the generator may fail to maintain the voltage required to work the magnets efficiently. In such a case, assuming that it is imperative for the magnets to have this big supply of current available, an additional generator is indicated so that the total amount of current at any time may not exceed ten ampéres from either of the generators. It is generally agreed that the voltage should not exceed twelve (volts), since a bigger voltage is liable to damage the contacts in course of time owing to sparking and excessive heat. The contacts themselves are made of carefully selected metals, of which silver is as good as any (judging by the expressed opinions of American and British engineers) in that it is hard-wearing, springy, and a good conductor of electricity. Phosphor-bronze is also an excellent contact metal, though it is said to refuse contact the first time in damp weather.


TOP BOARD
INVERTED RIBS
REGULATORS
FLOATING FRAME
TRUNK
WEIGHTS
TRUNK BAND
FEEDERS
RECEIVER OR WELL

BELLOWS & FEEDER.

FIG. 41

Tungsten and manganese have also been used. Platinum is also excellent, but much too expensive. In order to be reliable an electric action must (1) be protected from dust or grit, (2) consist of reliable magnets, (3) have efficient contacts, (4) be properly wired up, (5) have well arranged and protected cables, and a reliable source of low voltage current.

The wind in the days of our forefathers was invariably supplied by the hard work of a human organ blower. The Schulze organ in Doncaster Parish Church was originally supplied with wind by means of three tiers of diagonal bellows, each bellows being connected by a rope and pulley to a sliding panel in which a hole was provided for the blower's feet. Several men were employed in the operation of this mechanism. As a boy I can well remember watching the wretched man who was employed to blow the organ in my father's church endeavouring to keep the tell-tale down, his face bedewed with perspiration on a hot summer's evening, while the organist, all unheedful of the torture he was inflicting, drew great quantities of wind from the ridiculously inadequate reservoir that the organ builder had provided. Those evil days are over. Only small organs in country churches are now hand-blown, and the number of these is diminishing with the introduction of electricity from the grid in rural districts. The electric blower is the rule rather than the exception. Gas and water were both pressed into service in early efforts to provide mechanical blowing plant and not so very long ago the hydraulic engine operating the feeders in place of a man or boy was considered the best method. To-day, the rotary or fan blower driven by an alternating current motor is standard practice.

Let us, however, first look at the bellows illustrated in Fig. 41. The various parts are mentioned in the drawing. The feeders (worked up and down alternately) supply the pressure-wind to the reservoir above and against the resistance of the weights on the top board. Thus, the wind is squeezed out through the well into the outlet trunk and finds its way ultimately to the soundboards and pipes. In order to keep the wind flow steady and reasonably uniform, the two sections of the reservoir (divided by the floating frame) are constructed somewhat differently: the ribs of one are inverted so that the upper portion may counterbalance the lower. The regulators (or counterbalances) help to prevent the top board from rocking from side to side, but they cannot do this unless the weights are so distributed on the top board as to ensure a level rise and fall. I have found myself that the best method is to group all the weights close together in the centre of the top board and to leave the outside edges unencumbered: the reservoir will then be as firm as a rock. Single-rise reservoirs are frequently used in place of the double-rise shown in the drawing, and in place of weights (or in addition to them) stout spiral springs are fixed at each corner of the reservoir. I do not like single-rise reservoirs myself, unless some method of compensation is applied to ensure absolute steadiness of wind **and a uniform pressure whatever stops are being used.** Mr. Henry Willis has for some time employed such a device.

In the old days the size of the bellows was a highly important consideration, since they alone were responsible for the supply of wind to the pipes. The area of the top board of the reservoir was determined by the rule of "two square feet per stop," though this was considered by many to err on the small side and "two and a half feet per stop" was often preferred. Each manual department and the pedal was given its own separate reservoir—and rightly—the size of each reservoir being calculated in accordance with the number of stops it was expected to supply. In the modern organ the reservoir is no longer looked to to supply the wind: feeders are seldom provided even for emergency should the electric mains fail, since in any case the task of "keeping the wind in" would be beyond the capacity of a human blower. The wind is supplied by the fan at the required cubic capacity per minute, while the reservoirs are only employed for the purpose of (1) determining the pressure of wind, and (2) maintaining a constant and unvarying pressure of wind whatever demand may be made on the supply at any given moment. It will be seen that a much smaller reservoir can be employed for this dual purpose, though it is still necessary to have as many reservoirs as there are pressures, and desirable to have a separate reservoir for each independent department in order to ensure complete stability under all conditions of supply and demand. A separate reservoir is generally considered essential for the action wind if the drawstops and pistons and other controls are actuated by pneumatics, as these make sudden demands on the wind supply at the maximum pressure, and if a chord is being held at the same time by the player it will be unsteady owing to the shock wave introduced. The reservoir, as its name implies, stores the pressure-wind and so keeps a certain percentage of the cubic capacity stored in its well in reserve for emergency demands. In America it is usual to allocate a separate reservoir to the upper and lower portions of the manual pipe-work so as to prevent the larger pipes in the bass register from robbing the smaller pipes in the treble of wind when a succession of staccato chords is played in the bass and a treble note is held at the same time. In very many organs this acid test discloses an unstable wind supply which a single reservoir is unable to cope with. The only certain remedy is a balanced supply at both ends of the compass. The sizes of the trunks which are connected between the well of the reservoir and the various windchests must also be carefully planned so that the pressure-wind may flow at the required velocity under all circumstances. It is always well to err on the safe side and make the trunks too large than too small in cross-section. A wooden trunk needs to be larger than a corresponding metal one since the former is four-sided and its interior angles cause friction, while the metal trunk is always round: the fewer the angles and bends, and the shorter the trunk, the better.

In order to economise space a reservoir can be divided into two parts as shown in Fig. 45. In such a case it is essential to introduce some form of compensating device to ensure equal loading of each top board, otherwise the least difference in loading will cause the heavier to remain closed until the other is full. The arrangement shown in Fig. 45 is due to Mr. C. H. Clarke and is employed in his own organ. It will be seen that the two top boards are mechanically coupled by means of the levers **a**. To avoid a pin-and-slot sliding connection between the inner ends of these levers, the latter are connected by the links **b**, the connecting point **c** of which must be held against sideways movement. For this purpose radial links **d** are employed with their swinging ends connected by the short equalising link **e**. Links **d** and **e** are duplicated, one set being on each side(as shown). All links are of plywood, and all pivots are of brass with split-pin keeps. The device takes very little strain as it is only the difference between the two loads on either reservoir that is transmitted by it. I have seen this compensator at work and can testify to its complete efficiency.

The old type of reservoir used to have a safety-valve or trap fitted to its top board to prevent it from rising beyond a certain level, so that the human blower could not "overblow" the bellows, though he most certainly could make it pant and heave if he refused to stop pumping the handle after the reservoir had been fully supplied with wind. Only a few days ago I was asked to regulate some stops in a small organ in a very out-of-the-way village, since an organ builder could not be found to undertake the job. This instrument is still hand-blown and the doughty blower at first manipulated the handle with such vigour and persistence that it was quite impossible to regulate the gasping pipes. A few constructive hints, however, rectified matters and both regulation and tuning became practicable.

We will now revert to the electrically driven fan blower. The quantity of wind required to be supplied by the motor and fan is calculated in terms of so many cubic feet of wind per minute at so much pressure of wind. The degree of pressure can be measured either by an engineer's pressure gauge or else by means of an organ builder's wind-gauge (or anemometer). The latter instrument is illustrated in Fig. 42. The foot of the gauge is placed in the upperboard hole in lieu of the speaking pipe and the key depressed (the stop also being drawn): the water in the bent glass tube will immediately rise to a certain height. In the illustration it will be seen that the black water-line has risen to 18 inches on the left side of the glass tube, while on the right side it points to 6 inches. The pressure of wind is therefore $18-6=12$ inches. This could very easily represent the actual pressure measured at the output from the fan itself, or it could be the pressure taken at the tuba chest. It must, however, be borne in mind that the pressure reading assumes that the wind cannot escape at any point and that the water in the glass tube effectually seals the wind flowing into the foot of the gauge. It is necessary to see that there is sufficient water in the tube before measuring the pressure, so that the water-line on the right side of the bend may not be driven round to too low a level: also the gauge must be held as perpendicularly as possible. If a hole is bored at the side of a pipe-foot (anywhere between the toe and the mouth of a flue pipe or the toe and the block of a reed pipe) and the gauge fitted to this hole by means of a rubber tube, the actual reading will be less than that shown at the **upperboard** hole on which the pipe is standing, since there is a leakage of wind at the mouth of the flue pipe and at the top of the tube of the reed pipe. It is therefore obvious that the chest pressure is not the same as the pressure on which the pipe speaks: it is always more, because the gauge is airtight while the pipe is not.

How is the quantity of wind required to supply an organ calculated? Let us suppose that an electric fan blower is wanted for the organ whose specification is given on page 225, namely that of the baroque instrument in the Worcester Art Museum, Mass., U.S.A. It so happens that I do not know what size of blower has been provided for this particular organ, never having enquired. I propose, therefore, to make my own estimate of the amount of wind required for this organ; and if I had to place an order for a new blower capable of delivering the wind supply needed I should give the manufacturer the necessary data enabling him to choose the right type and size of blower for the object in view. He would have no difficulty in estimating the horse power capable of standing up to the load imposed on the motor and fan, and the size of fan or fans capable of supplying the head of wind required. So let us make our calculation.

Each stop of pipes on each manual and on the pedal is reckoned to consume a certain number of cubic inches of wind per second. I calculate the number of cubic inches required for the lowest pipe of a stop and multiply that figure by 5: thus, I get the number of cubic inches per second consumed by that particular stop if I play a major common chord consisting of middle C and the following six notes below in order: tenor G, tenor E, tenor C, GG, EE, CC.

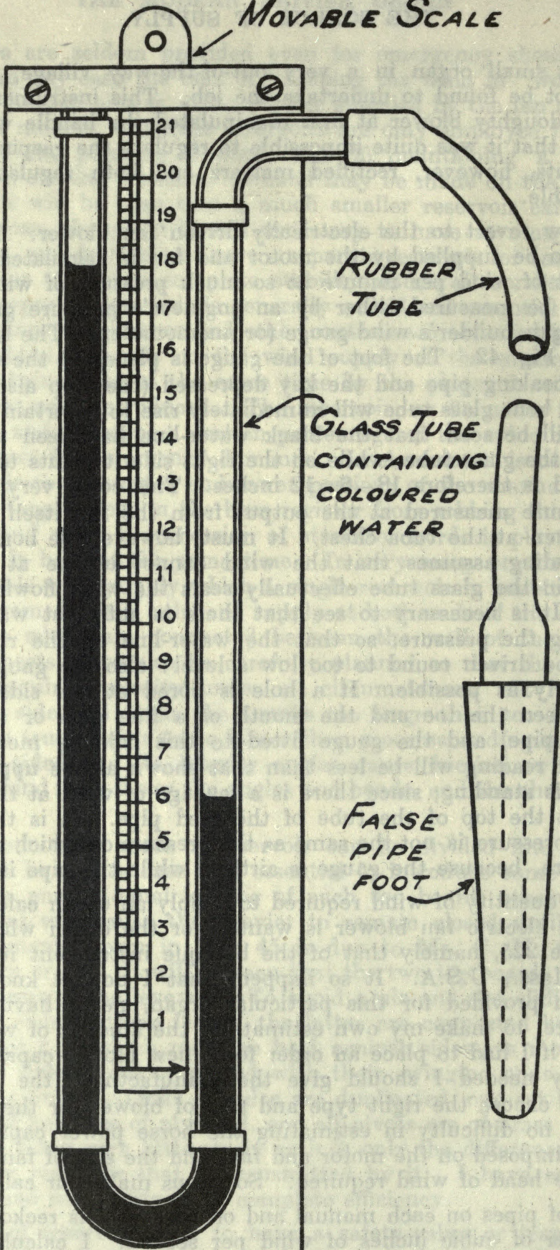

MOVABLE SCALE
RUBBER TUBE
GLASS TUBE CONTAINING COLOURED WATER
FALSE PIPE FOOT
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

FIG. 42

WINDGAUGE.

The actual multiplier lies between 4 and 5 times the figure for CC: I choose × 5 for safety.

The great manual has five stops, and I assess the wind consumption as follows:—

Quintaton, 16 ft.,	300 × 5	=	1,500	cubic in.	per sec.
Bourdon, 8 ft.,	200 × 5	=	1,000	,,	,,
Principal, 4 ft.,	180 × 5	=	900	,,	,,
Rohrflöte, 4 ft.,	100 × 5	=	500	,,	,,
Fourniture,	230 × 5	=	1,150	,,	,,
			5,050	cubic in.	per sec.

To the above total I add ten per cent. for the wind required to work the pneumatic action, making the total 5,555 cubic in. per sec.

The positif manual requires the following wind supply:—

Quintade, 8 ft.,	200 × 5	=	1,000	cubic in.	per sec.
Koppelflöte, 4 ft.,	150 × 5	=	750	,,	,,
Nazard, 2⅔ ft.,	95 × 5	=	475	,,	,,
Doublette, 2 ft.,	90 × 5	=	450	,,	,,
Tierce, 1-3/5 ft.,	85 × 5	=	425	,,	,,
Larigot, 1⅓ ft.,	80 × 5	=	400	,,	,,
			3,500	cubic in.	per sec.

Adding ten per cent. for action, we get a total of 3,850 cubic in. per sec.

The recit manual requires 4,042 cubic in. per sec.: thus:—

Rohrflöte, 8 ft.,	165 × 5	=	825	cubic in.	per sec.
Prestant, 4 ft.,	180 × 5	=	900	,,	,,
Cymbel,	220 × 5	=	1,100	,,	,,
Cromorne, 8 ft.,	170 × 5	=	850	,,	,,
			3,675	cubic in.	per sec.
	Add 1/10th,		367	,,	,,
			4,042	cubic in.	per sec.

The pedal organ requires sufficient wind to supply two pedal notes, CCC and GGG, sounded simultaneously on all stops drawn. For safety we may multiply the cubic capacity of each stop by two, and add ten per cent. for action, thus:—

Rohr Bourdon, 16 ft.,	450 × 2	=	900	cubic in.	per sec.
Principal, 8 ft.,	250 × 2	=	500	,,	,,
Nachthorn, 4 ft.,	100 × 2	=	200	,,	,,
Blockflöte, 2 ft.,	90 × 2	=	180	,,	,,
Fourniture,	250 × 2	=	500	,,	,,
Posaune, 16 ft.,	400 × 2	=	800	,,	,,
Trompette, 8 ft.,	220 × 2	=	440	,,	,,
Rohr Schalmei, 4 ft.,	120 × 2	=	240	,,	,,

N.B.—The Quintaton, 16 ft. and 8 ft., being derived from the great manual, has already been assessed.

The total consumption of the above pedal organ will be 3,760 cubic in. per sec. plus ten per cent., which amounts to 4,136 cubic in. per sec. The four totals above worked out are:—

5,555
3,850
4,042
4,136

Grand total, 17,583 cubic in. per sec.

We have now to convert the cubic in. to cubic feet and the seconds to minutes. Dividing the above total by 1,728 we get 10.175 cubic feet per second: multiplying by 60, we get 610 cubic feet per minute. An electric blower capable of delivering 600 to 650 cubic feet of wind at 2½ in. pressure (the actual pressure on which the pipes are voiced throughout) will be ample for this organ. If, however, the pneumatic action is supplied by wind from the fan and therefore at a higher pressure, we should have to allow for this and work out a separate figure for the action. Supposing the organ builders want 7 in. for the pneumatics: then we can take the four totals we calculated for each department of pipe-work without the addition of the ten per cent. for action in each case, thus:—

5,050
3,500
3,675
3,760

15,985 cubic in. per sec.

We now have to supply 550 cubic feet of wind per minute at 2½ in. pressure for the pipe-work. For the action wind we shall require a tenth of the above figure at 7 in., namely 55 cubic feet of wind per minute at 7 in. With a single-stage fan only one pressure can be measured at its output, so that we should have to ask for 550 cubic feet per minute at 2½ in. plus 55 cubic feet multiplied by the difference between 7 and 2½ in. The additional quantity will be 154 cubic feet, and the total 704 cubic feet per minute at 2½ in.

If a two-stage fan blower is employed, in which the first fan giving the lower pressure delivers its output into the intake of the second fan, then the latter fan gives the higher pressure at a reduced cubic output capacity: the low pressure reservoirs will be fed by the first fan output, and the action reservoir by the second fan output. Three, four or even five fans can be coupled in series in this manner in order to build up the pressure to the required maximum. For the more moderate-sized organ not taking more than 300 cubic feet at 7 in. pressure, a single-stage fan blower is usually deemed adequate, since the fan can be made to revolve at a datum speed of 3,000 r.p.m. by a 1 horse-power A.C. motor coupled to the fan spindle by means of a "V-belt" drive and geared to the desired ratio by means of pulleys.

Although I have described the method by which I calculate the total wind supply required for a given size of organ, it is seldom necessary for the amateur organist to take this trouble in placing an order for a new electric blower, since reputable makers of electric blowing apparatus are willing to supply the optimum size of blower provided that they are given the full specification of the organ including couplers and controls together with the pressures allotted to the various departments. The situation of the blower, relative to the organ, should also be taken into account.

We have seen that the output of the blower is conducted to the reservoirs by means of a trunk. In order that the rise of the top board of the reservoir so supplied may be under control, a roller-pallet box is fitted at some point

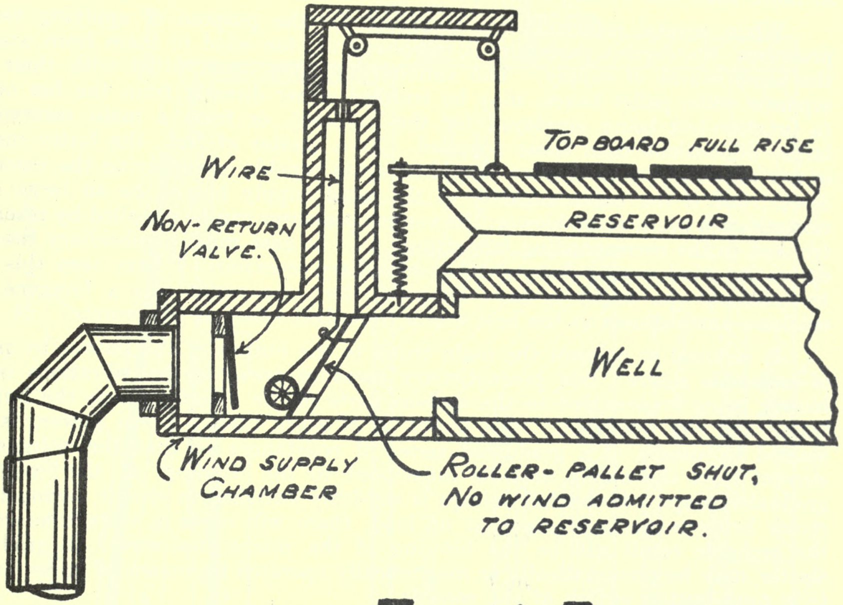


FIG. 43
ROLLER-PALLET BOX.

between the fan and the well of the reservoir. In Fig. 43 is shown a typical form of roller-pallet attached to the well of the reservoir. Here the reservoir is at its maximum permissible rise and is unable to rise any further owing to the fact that the roller-pallet is completely closed over the inlet orifice admitting wind to the well, thus shutting off wind supply from the fan. The orifice is usually constructed in the form of a grid. The fan is, of course, working at full speed just the same, but its supply is cut off from the reservoir. As soon as the reservoir top board begins to fall, through wind being drawn from its storage by the organist, the cord attached to the top board pulls up the roller and a fresh supply of wind is admitted from the fan, increasing in quantity as the roller uncovers more and more of the inlet hole. Thus the roller-pallet automatically controls the wind supply to the reservoir according to the demand made on it by the organist. The non-return valve is placed between the supply trunk and the roller-pallet in order to prevent any wind passing back to the fan when the reservoir is collapsing and re-filling. Actually, the non-return valves should be placed as close to the output of the fan as possible, and not at the reservoir end, since otherwise an objectionable noise is likely to be heard as the wind is driven through the trunk, especially if the latter is of some length (as it often is). Nine-tenths of the noise is eliminated if the non-return valves are arranged in a separate box and the box is fitted to the output of the fan. It is surprising how few engineers seem to be aware of this fact, which I have proved beyond doubt in more than one instance when called upon to solve "noise troubles."

When several reservoirs are employed for the purpose of applying various pressures, the correct procedure is to convey the fan wind to them from one and the same source of supply. The various reservoirs, each fitted with their own separate roller-pallet boxes, may be trunked either directly from the fan output (a junction-box being employed for the purpose), or from a main reservoir of larger dimensions than those supplied. As a matter of fact, the latter method is not necessary since the fan should be quite capable of supplying the reservoirs direct; and if the cubic capacity of the wind supply has to be so large as to necessitate a multi-stage blower, the various pressures can be supplied by reservoirs trunked to the corresponding fan-outputs. In no case must a subsidiary reservoir derive its wind supply from another subsidiary reservoir. I have seen this done by builders who ought to have known better: the result was a foregone conclusion—unsteadiness at the best and a tremulant effect at the worst.

It is usual to connect the main trunk to the output of the blower by means of a flexible sleeve: this precautionary measure prevents the vibrations of the blower being transmitted to the various parts of the organ such as the building frame and the reservoirs. The motor, if of more than ¾ horse power, is best started by means of a graduated series of resistances so that the voltage and current from the mains may be introduced to the winding of the motor in graduated steps. If the full voltage is suddenly switched in circuit, owing to the motor being made to start up at no load, there will occur a voltage surge and the probable result will be the blowing of the mains fuse-wire. A graduated starter may be pneumatically or magnetically operated by means of an on and off twin push-button switch at the console.

Fan blowers are housed in scientifically designed silencing chambers, the interior walls of which are lined with non-inflammable material (such as "everite") to satisfy the requirements of the insurance companies. A properly designed inlet hole must be made in the most appropriate spot in the wall of the chamber to allow access for outside air, and in order to prevent dust being drawn into the trunks and soundboards this hole should be protected by a sheet of gauze. **the area of the hole being made sufficiently large to allow for the slightly obstructing effect of the gauze on the passage of air into the chamber.**

An old and popular device for imitating the vibrato effect of orchestral instruments (and, I may add, of too many modern vocalists) is the **tremulant.** It is mentioned here because it is intimately associated with the wind supply, its object being to shake the wind in the reservoir and soundboard and so cause the pipe note to vibrate. This effect is, as everyone knows, a characteristic feature of the cinema organ which appears to rely on the tremulant for its successful appeal to British audiences: The King of Instruments does not depend on such a contrivance for its tonal effectiveness any more than the well-trained vocalist; yet the vibrato effect has its uses in both spheres of musical expression. A well-designed tremulant is unquestionably of service to the performer of modern

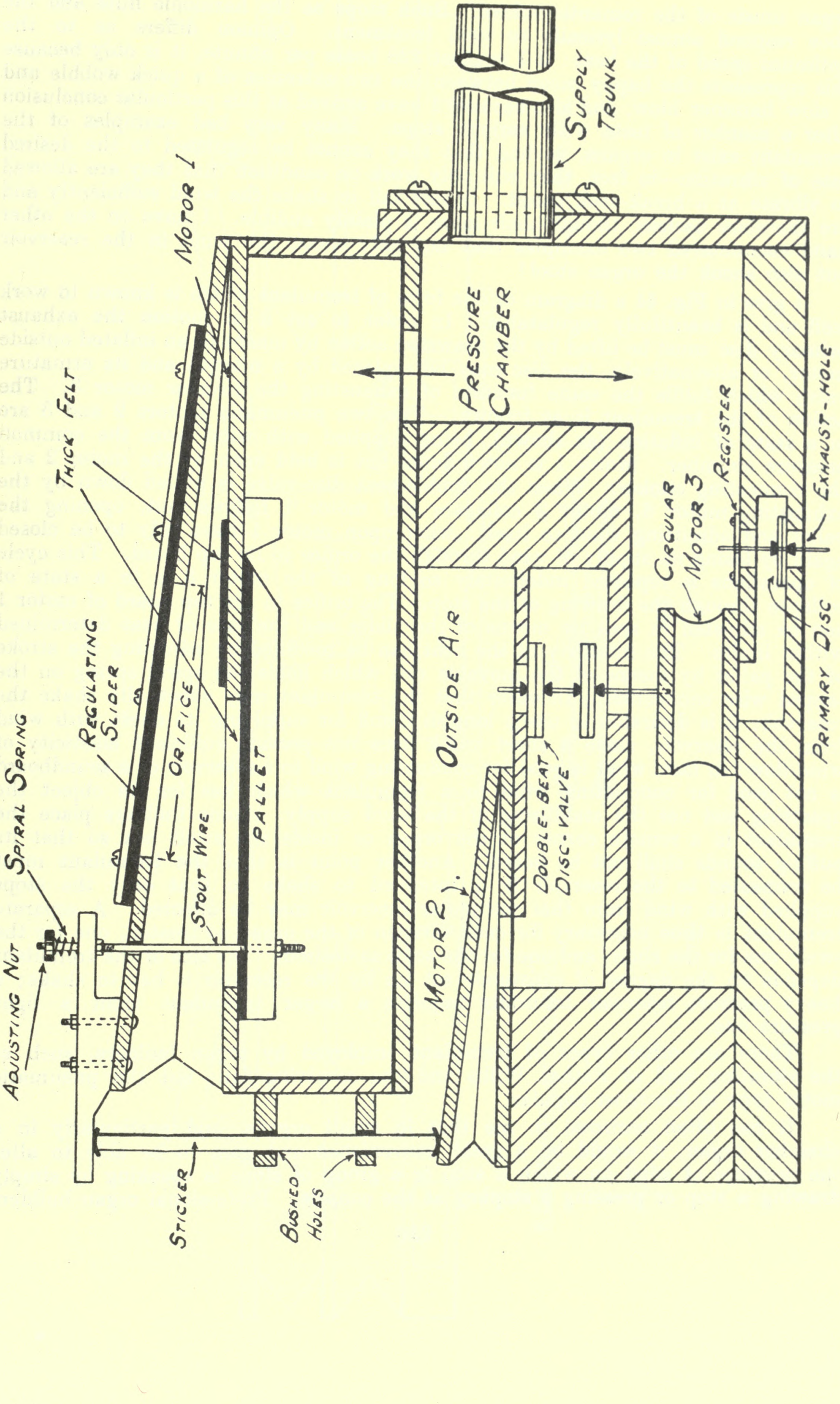

Supply Trunk
Motor 1
Pressure Chamber
Thick Felt
Register
Exhaust-hole
Circular Motor 3
Regulating Slider
Orifice
Outside Air
Primary Disc
Spiral Spring
Stout Wire
Pallet
Double-Beat Disc-Valve
Motor 2
Adjusting Nut
Sticker
Bushed Holes

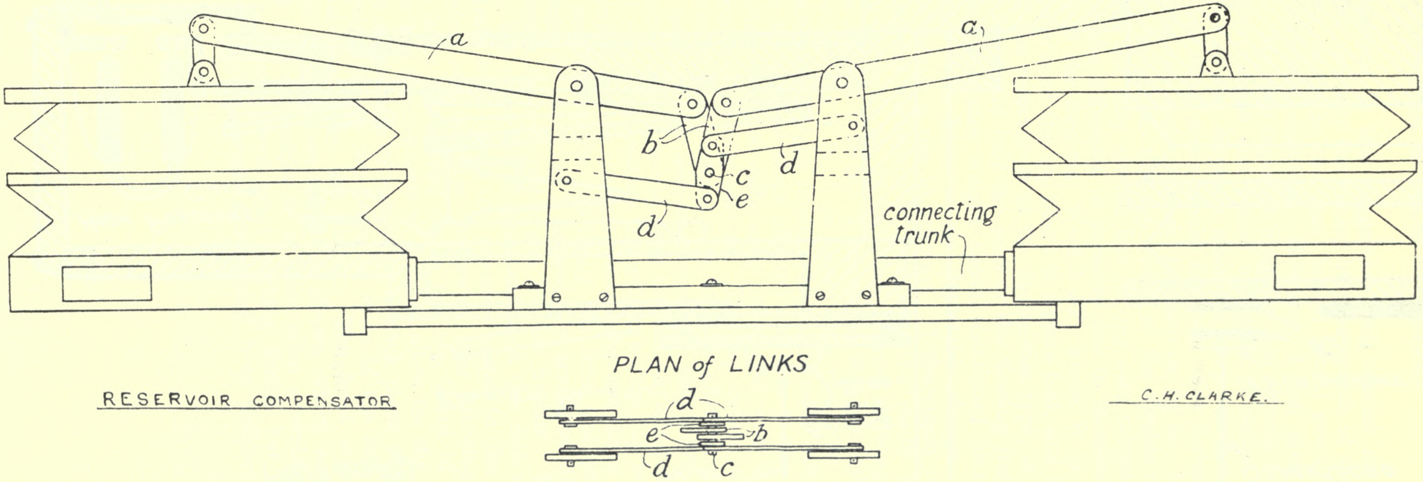
FIG. 44
TREMULANT.

organ music of the romantic school. Such stops as the harmonic flute and the oboe respond almost lyrically to such treatment. Opinion differs as to the optimum speed of the beat: if I suggest 228 beats per minute, it is only because this represents the happy mean between the two extremes of a quick wobble and a slow hammer blow, and also because I have arrived at this particular conclusion after a number of tests with various stops. Many very bad examples of the tremulant exist in organs, so bad that they cannot be regulated to the desired rate of vibration—in fact, they will only work on condition that they are allowed to vibrate at a break-neck speed. Others fail to shake the wind sufficiently and are therefore useless, though their noise is plainly audible. I have on the other hand encountered two examples that not only shook the wind in the reservoir but also shook the organ stool!

I give in Fig. 44 a diagram of one form of tremulant which is known to work well and is beautifully regulatable. In order to set it in motion the exhaust primary disc must be lifted by the drawstop action by means of an inflated outside motor, or alternatively, the disc may be replaced by a magnet and its armature valve which fulfils the same function of exhausting the circular motor 3. The action of the tremulant is as follows:—The two pneumatic motors 2 and 3 are in a state of inflation (as shown), being supplied with wind from the common pressure chamber. Motor 1 is not inflated but is held open by the motor 2 and the connecting sticker. When the double-beat disc-valve is pulled down by the exhausting motor 3, motor 2 collapses and motor 1 follows suit, opening the pallet and admitting wind to itself: whereupon motor 1 rises only to be closed again by losing its supply of wind through the orifice in its top board. This cycle of operations is repeated indefinitely so long as the motor 3 is in a state of collapse through the drawing of the stop. The orifice in the top board of motor 1 can be adjusted in area by means of the slider and the rate of beat determined within limits. The intensity of the beat can be modified by adjusting the stroke of the pallet by means of the movable nut which holds the spiral spring on the tapped wire connection. In order that the tremulant may effectually shake the reservoir, it is desirable to use a longish trunk for supplying its chest with wind from the reservoir, since a short trunk does not provide sufficient elasticity of wind-flow: in fact, what is good for conducting wind to a reservoir or a soundboard is not good for conducting wind to a tremulant which has for its object the upsetting and not the stabilising of the wind supply. Some builders place the tremulant in a remote corner of the organ or inside the swell box so that its puffing sounds shall not be heard. Another point is that the tremulant must be connected to the reservoir it is intended to shake so that only the stops supplied with wind from that particular reservoir may be affected. A separate tremulant is thus necessary for each division of the organ so treated, one for the swell, one for the choir, and one for the solo, as desired. The size of the tremulant depends on the degree of resistance set up by the reservoir it has to shake; a heavy pressure reservoir naturally requires a larger tremulant than a light pressure one.

There are other types of tremulant employed by organ builders, such as the vibrating reed of Father Willis and the revolving fan; but the pneumatic motor type is the most popular.

It has often occurred to me that in small organs, and particularly in a chamber organ, it would be a great convenience and gain to be able to alter the pressure of wind on which a stop or a group of stops is speaking by simply drawing a stop or pressing a stopkey at the console. Professional organ builders

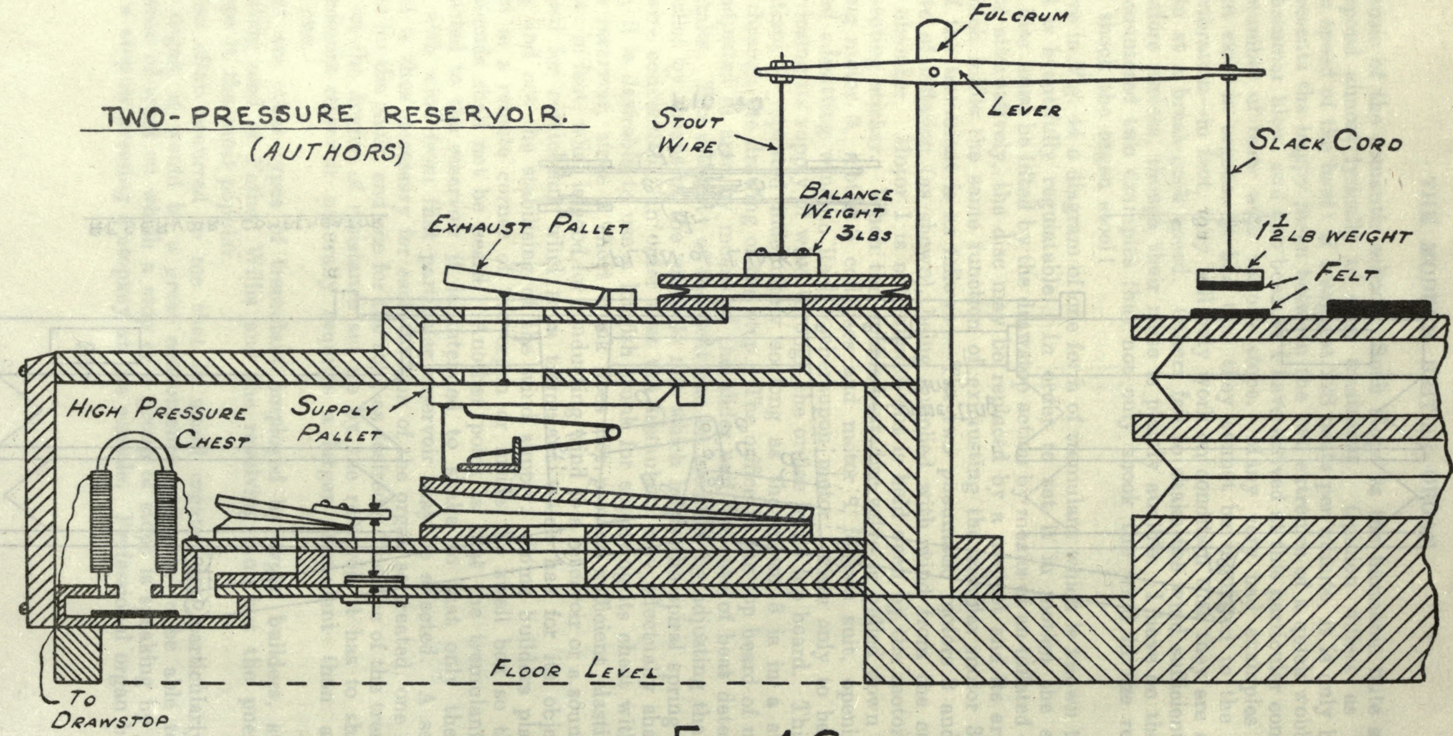

a
a
b
c
e
d
d
connecting trunk
d
e
b
d
c

PLAN of LINKS

RESERVOIR COMPENSATOR

C.H. CLARKE.

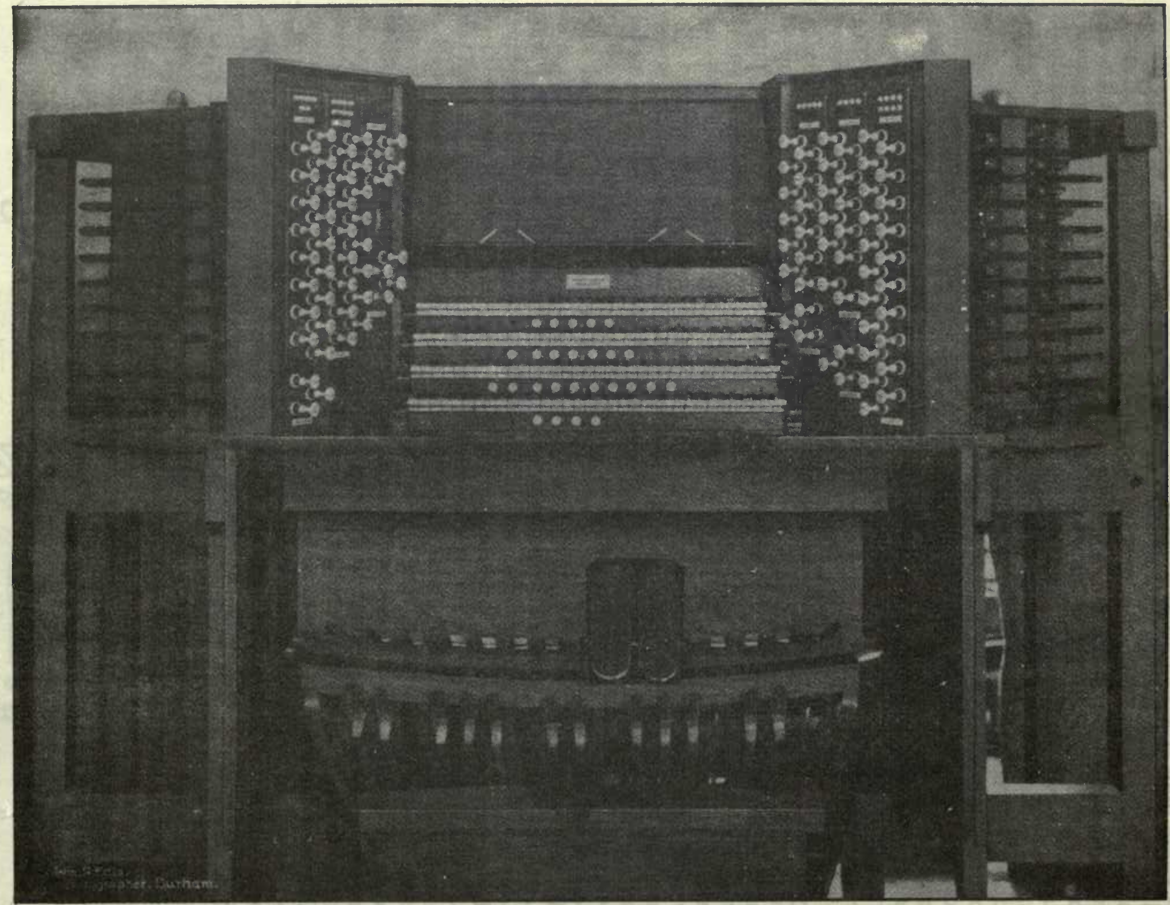
FIG 45.


Fulcrum
Lever
Stout Wire
Slack Cord
Balance Weight 3lbs
1½lb Weight
Felt
Exhaust Pallet
Supply Pallet
High Pressure Chest
Floor Level
To Drawstop

TWO-PRESSURE RESERVOIR.
(AUTHORS)

FIG. 46

may raise their eyebrows at this suggestion and remind me that any change of pressure must alter not only the tuning but the speech of the pipes so affected. In strict theory, this would be the case, but in actual practice the pitch of the pipes need not be seriously modified. However, I can give an example from my own experience. My own organ at Stagsden has a group of old stops retained from the original barrel-organ and voiced on 2⅜ in. pressure. It is well known that organ flue pipes of the diapason class are very sensitive to their pressure supply, more sensitive than many would suppose. For instance, after carefully voicing and regulating my early English diapason on 2¼ in., I tried the effect of adding a two ounce weight to the top board of the double-rise reservoir. The tone of the stop was not only altered but (to my ear) ruined. Now it is easily possible to calculate the difference in pressure due to increasing the load on the reservoir by means of the formula, $W=5.2\ AP$, where W is the weight of load in pounds, A is the area of the top board in square feet, and P is the pressure of wind in inches. If the reservoir is of the double-rise type, it is necessary to add to the area of the top board half the area of the floating frame from rib to rib. The addition of the two ounce weight above mentioned increased the pressure by 1/200 in. ! There was, however, no detectable change in either power or pitch with so infinitesimal a rise in pressure. I thereupon revoiced the stop so as to allow for marginal variations of pressure; the result was that the pipes were able to speak correctly on 2⅜ in. wind without showing any sign of faulty articulation with a drop of 1/16 in. I calculated that the latter drop in pressure would occur if a weight of 1 lb. 7 oz. were removed from the reservoir. The removal of this particular weight made a very noticeable difference in the power and quality of the six manual stops affected and also in the power of the pedal bourdon. The tuning was not sufficiently interfered with to prevent the stops being used at a Sunday evening service. The top octave of the principal and the two top octaves of the mixture were slightly affected, but these particular octaves were not used in the accompaniment of the service, and if they had been I doubt whether anyone would have noticed anything amiss. If, therefore, the organist could remove or restore the weight on the top board of the reservoir by means of a control at the console, would he not have at his disposal an extremely useful contrivance for modifying the tone and power of some of his stops? In pursuance of this idea I devised the arrangement shown in Fig. 46, with all due apologies to my good organ builder friends. The drawstop action is simple enough; the energised magnet exhausts the disc-valve and the pallet drops so as to admit wind from the pressure chest to the parallel-rise motor. The latter is inflated and operates the lever, thus allowing the weight at the other end of the lever to descend on to the top board of the reservoir. The parallel-rise motor has a movement of 4 in. to allow for the reservoir movement, and the weight is suspended by means of a slack piece of cord so as to ensure the weight remaining on the top board in spite of the fall of the latter during the demands made on it by the player. The lever arm must be correctly balanced by means of a balance weight as shown, which would be approximately twice that of the bellows weight or a little more according to the position of the fulcrum. I have not given exact working details but merely indicated one method of control. I can certainly commend it to builders of house organs as worthy of trial.



CONSOLE OF YORK MINSTER (Harrison & Harrison)

(Not referred to in Chapter XIII)

FOUR NOTABLE BRITISH ORGANS

The Organ in Doncaster Parish Church

THIS historic organ by Schulze & Sons of Paulinzelle, Saxony, was originally installed in 1862, following a fire in 1853 that destroyed the previous building and organ.

In 1894, the organ was rebuilt by Messrs. Abbott & Smith, of Leeds, who fitted a new console and action (partly tubular pneumatic) and increased the coupling and accessory facilities. At the same time gas engine blowing was installed to replace the old foot blowing gear requiring the services of several men.

The organ was always a five-manual instrument of approximately the same size as it exists to-day, but the original solo organ was duplexed from the swell stops. In 1910 when the organ was further rebuilt by Messrs. Norman & Beard, of Norwich, and the whole organ equipped with tubular-pneumatic action, a separate solo organ was installed, several new stops added and most of the old reeds revoiced. Also the blowing plant was then converted to electric power supplying up to 15 inches wind pressure. The present Rockingham electric fan blowing plant was provided a few years ago and is accommodated in a building in the churchyard.

In 1935 the organ was restored by Messrs. J. W. Walker & Sons. Their work included electrification of the entire action, new detached stop-key console (with the old keyboards incorporated), cleaning and renovation of the pipework and the provision of three additional double-rise reservoirs with new trunking to ensure wind steadiness and to replace the twelve old Schulze diagonal feeders, which of late had been used as reservoirs.

The pipework generally was treated with a view to restoration and retention of its original Schulze character. It is hoped that further work on some of the reed stops may be entertained at some future date. Provision on the console has been made for some future additions, these stops being shown thus * in the specification.

The speaking stops in the specification are shown in the order of the stop-keys on the jambs. The old names and original spelling have mostly been retained. The provision of new electrical coupling mechanism and combination action has included increased coupling facilities and provided for a very adequate supply of accessories.

The general arrangements of the console and electrical design were carried out in consultation with Dr. P. Saunders and Mr. Reginald Whitworth.

Compass of Manuals, CC to A - - - 58 Notes
Compass of Pedalboard, CCC to F - - 30 Notes

Great Organ

1.	Sub Bass T.C.	32 ft.
2.	Double Open Diapason	16
3.	Bourdon	16
4.	Open Diapason, No. 1	8
5.	Open Diapason, No. 2	8
6.	Open Diapason, No. 3	8
7.	Stopped Diapason	8
8.	Hohl Flute	8
9.	Stopped Flute	4
10.	Principal	4
11.	Gemshorn	4
12.	Quint	$5\frac{1}{3}$
13.	Twelfth & Fifteenth	2 ranks
14.	Mixture	5 ranks
15.	Cymbal	3 to 5 ranks
16.	Cornet	4 ranks
17.	Double Trumpet	16
18.	Posaune	8
19.	Trumpet	8
20.	Clarion	4

Swell Organ

1.	Bourdon	16 ft.
2.	Open Diapason	8
3.	Terpodion	8
4.	Echo Gamba	8
5.	Voix Celeste T.C.	8
6.	Harmonic Flute	8
7.	Rohr Flute	8
8.	Harmonic Flute	4
9.	Stopped Flute	4
10.	Principal	4
11.	Viol d'Amour	4
12.	Mixture	5 ranks
13.	Scharf	3 ranks
14.	Cornet	4 ranks
15.	Double Bassoon	16
16.	Trumpet	8
17.	Horn	8
18.	Hautboy	8
19.	Clarion	4
20.	Vox Humana	8
	Tremulant	

Choir Organ

1.	Lieblich Bourdon	16 ft.
2.	Geigen Principal	8
3.	Viol da Gamba	8
4.	Flauto Gambe (2 ranks)	8
5.	Gemshorn	8
6.	Salicional	8
7.	Flauto Traverso	8
8.	Lieblich Gedact	8
9.	Flauto Traverso	4
10.	Lieblich Flute	4
11.	Geigen Principal	4
12.	Quintaten	4
13.	Flautina	2
*14.	Trompette	8

Solo Organ

*1.	String Celeste T. C.	8
2.	String Gamba	8
3.	Harmonic Clarabel Flute	8
4.	Concert Flute	4
5.	Clarinet	8
6.	Orchestral Oboe	8
	Tremulant	
7.	Tuba	8
	MUTATIONS (in Solo Box)	
*8.	Nazard	$2\frac{2}{3}$
*9.	Piccolo	2
*10.	Tierce	$1\frac{3}{5}$
*11.	Septieme	$1\frac{1}{7}$
*12.	Octave Piccolo	1

Echo Organ

1.	Tibia Major	16 ft.
2.	Harmonica	8
3.	Vox Angelica	8
4.	Flauto Amabile	8
5.	Flauto Traverso	8
6.	Celestina	4
7.	Flauto Dolcissimo	4
8.	Harmonica Aetheria	2 ranks
*	Tremulant	

Couplers

1. Choir to Pedal.
2. Great to Pedal.
3. Swell to Pedal.
4. Solo to Pedal.
5. Echo to Pedal.
6. Swell to Great.
7. Choir to Great.
8. Solo to Great.
9. Solo to Swell.
10. Swell Octave.
11. Swell Sub Octave.
12. Swell Unison Off.
13. Swell to Choir.
14. Solo to Choir.
15. Echo to Choir.
16. Solo Octave.
17. Solo Sub Octave.
18. Solo Unison Off.
19. Second Touch Canceller.
20. Great and Pedal Combinations coupled.
21. Three-way Switch
    (1) Mutations on Solo.
    (2) Mutations on Choir.
    (3) Mutations on Choir and Solo.

Pedal Organ

1.	Sub Principal	32 ft.
2.	Major Bass	16
3.	Principal Bass	16
4.	Open Bass	16
5.	Violone	16
*6.	Dulciana	16
7.	Sub Bass	16
8.	Major Bass	8
9.	Flute Bass	8
10.	Violoncello	8
11.	Octave Bass	8
12.	Quint Bass	$10\frac{2}{3}$
13.	Great Tierce	$6\frac{2}{5}$
14.	Quint	$5\frac{1}{3}$
15.	Fifteenth Bass	4
16.	Tierce	$3\frac{1}{5}$
17.	Mixture	2 ranks
18.	Cymbal	2 ranks
19.	Contra Posaune	32
20.	Posaune	16
21.	Bombard	16
22.	Contra Fagotto	16
*23.	Bassoon (Sw)	16
24.	Trumpet	8
25.	Horn	8
26.	Fagotto	8
27.	Clarion	4

Accessories

Eight Thumb Pistons to Great.
Eight Thumb Pistons to Swell.
Six Thumb Pistons to Choir.
Three Thumb Pistons to Echo.
Four Thumb Pistons to Solo.
Eight Toe Pistons to Pedal.
Eight Toe Pistons to Swell (duplicating).

One Reversible Toe Piston for Great to Pedal.
One Reversible Toe Piston for Swell to Pedal.
One Reversible Toe Piston for Choir to Pedal.
One Reversible Toe Piston for Solo to Pedal.
One Reversible Thumb Piston for Great to Pedal
One Reversible Thumb Piston for Swell to Great.
One Reversible Thumb Piston for Solo to Great.

Balanced Swell Pedal.
Balanced Solo Pedal.
Balanced Echo Pedal.

ELECTRO-PNEUMATIC ACTION.

DETACHED CONSOLE IN OAK.

WALKER STOP-KEY CONTROL with patented double-touch cancelling. Combinations adjustable by lever switch board at rear of console.

ROCKINGHAM ELECTRIC BLOWER AND GENERATOR.

The Organ in Westminster Abbey

THE organ was built by Messrs. Harrison and Harrison, and was used for the first time at the Coronation of His Majesty King George the VI on the 12th May, 1937.

The specification was drawn up by Sir Walter G. Alcock, M.V.O., Mus. Doc., Sir Edward Bairstow, Mus. Doc., Sydney H. Nicholson, Esq., M.V.O., Mus. Doc., and Ernest Bullock, Esq., C.V.O., Mus. Doc., Organist of the Abbey, in consultation with the builders.

The Great and Choir Organs and the larger portion of the Pedal are within the two side cases in the nave. The Swell and Solo organs, the Pedal Ophicleides and the 32 ft. pipes of the Pedal Open Wood are in the south triforium of the nave. The Echo organ will be placed in the triforium east of the choir of the church. The console occupies a central position on the screen.

There are four manuals, CC to C, 61 notes, and two-and-half octaves of radiating and concave pedals, CCC to G, 32 notes; 102 speaking stops and 34 couplers, etc. (including the Echo organ), making a total of 110 drawstops and 26 tablets.

Pedal Organ, 18 Stops, 5 Couplers.

				feet
1.	Double Open Wood	(20 from No. 3)	Wood,	32
2.	Open Wood I		,,	16
3.	Open Wood II		,,	16
4.	Open Diapason		Metal,	16
5.	Geigen	(from No. 36)	,,	16
6.	Sub Bass	(from No. 37)	Wood,	16
7.	Dulciana	(from No. 19)	Metal,	16
8.	Viole	(from No. 68)	,,	16
9.	Octave Wood	(20 from No. 2)	Wood,	8
10.	Principal	(20 from No. 4)	Metal,	8
11.	Flute	(from No. 37)	Wood,	8
12.	Fifteenth	(20 from Nos. 4 and 10)	Metal,	4
13.	Mixture	12, 17, 19, 22	,,	—
14.	Double Ophicleide	(20 from No. 15)	,,	32
15.	Ophicleide		,,	16
16.	Tuba	(from No. 80)	,,	16
17.	Clarinet	(from No. 76)	,,	16
18.	Posaune	(20 from No. 15)	,,	8

I. Choir to Pedal.
II. Great to Pedal.
III. Swell to Pedal.
IV. Solo to Pedal.
V. Solo Octave to Pedal.

Choir Organ, 17 Stops, 5 Couplers.

				feet
19.	Contra Dulciana		Metal,	16
20.	Open Diapason		,,	8
21.	Claribel Flute		Wood,	8
22.	Viola da Gamba		Metal,	8
23.	Dulciana		,,	8
24.	Stopped Diapason		Wood,	8
25.	Gemshorn		Metal,	4
26.	Nason		Wood,	4
27.	Flauto Traverso		Metal,	4
28.	Twelfth		,,	2⅔
29.	Gemshorn Fifteenth		,,	2
30.	Tierce		,,	1⅗
31.	Dulciana Mixture	19, 22	,,	—
32.	Cornopean	(harmonic trebles)	,,	8

VI. Super Octave.
VII. Sub Octave.
VIII. Unison Off.
IX. Swell to Choir.
X. Solo to Choir.

Nos. 19 to 32 in a swell-box.

33.	Contra Tromba	from Great	Metal,	16
34.	Tromba		,,	8
35.	Octave Tromba		,,	4

Great Organ, 16 Stops, 3 Couplers.

Stop			feet
36. Double Geigen		Metal,	16
37. Bourdon		Wood,	16
38. Open Diapason I		Metal,	8
39. Open Diapason II		,,	8
40. Open Diapason III		,,	8
41. Geigen		,,	8
42. Hohl Flute		Wood,	8
43. Octave		Metal,	4
44. Geigen Principal		,,	4
45. Octave Quint		,,	2⅔
46. Super Octave		,,	2
47. Mixture	15, 19, 22, 26, 29	,,	—
48. Harmonics	17, 19, 21, 22	,,	—
49. Contra Tromba		,,	16
50. Tromba	(harmonic)	,,	8
51. Octave Tromba	(harmonic)	,,	4

XI. Choir to Great.
XII. Swell to Great.
XIII. Solo to Great.

Swell Organ, 16 Stops, Tremulant and 4 Couplers.

Stop			feet
52. Quintaton		Metal,	16
53. Open Diapason		,,	8
54. Lieblich Gedeckt		Metal and Wood,	8
55. Viole d'Amour		Metal,	8
56. Salicional		,,	8
57. Vox Angelica	ten C.	,,	8
58. Principal		,,	4
59. Lieblich Flute		,,	4
60. Twelfth		,,	2⅔
61. Fifteenth		,,	2
62. Mixture	15, 19, 22, 26, 29	,,	—
63. Contra Oboe		,,	16
64. Oboe		,,	8

XIV. Tremulant.

Stop			feet
65. Double Trumpet		,,	16
66. Trumpet	(harmonic trebles)	,,	8
67. Clarion	(harmonic trebles)	,,	4

XV. Octave.
XVI. Sub Octave.
XVII. Choir to Swell.
XVIII. Solo to Swell.

Solo Organ, 17 Stops, TREMULANT AND 3 COUPLERS.

				feet
68.	Contre Viole		Metal,	16
69.	Viole d'Orchestre		,,	8
70.	Viole Céleste		,,	8
71.	Viole Octaviante		,,	4
72.	Cornet de Violes	10, 12, 15	,,	—
73.	Harmonic Flute		,,	8
74.	Concert Flute		,,	4
75.	Harmonic Piccolo		,,	2
76.	Double Clarinet	(49 from No. 77)	,,	16
77.	Clarinet		,,	8
78.	Cor Anglais		,,	8
79.	Orchestral Hautboy		,,	8
XIX.	TREMULANT.			
80.	Contra Tuba	(49 from No. 81)	,,	16
81.	Tuba	(harmonic)	,,	8
82.	Orchestral Trumpet		,,	8
83.	French Horn	(harmonic)	,,	8
	Nos. 68 to 83 in a swell-box.			
84.	Tuba Mirabilis	(harmonic)	,,	8

XX. OCTAVE.
XXI. SUB OCTAVE.
XXII. UNISON OFF.

Combination Couplers.

XXIII. PEDAL TO CHOIR PISTONS.
XXIV. GREAT AND PEDAL COMBINATIONS COUPLED.
XXV. PEDAL TO SWELL PISTONS.
XXVI. PEDAL TO SOLO PISTONS.

Accessories.

Eight adjustable combination foot pistons to the Pedal organ.
Eight adjustable combination pistons to the Choir organ.
Eight adjustable combination pistons to the Great organ.
Eight adjustable combination pistons to the Swell organ.
Eight adjustable combination foot pistons (duplicating) to the Swell organ.
Nine adjustable combination pistons to the Solo organ.
One adjustable general piston.
Reversible piston to No. 15.
Reversible foot piston to GREAT TO PEDAL.
Reversible piston to GREAT TO PEDAL.
Reversible foot piston to SWELL TO GREAT.
Reversible piston to SWELL TO GREAT.
Reversible foot piston to SOLO TO GREAT.
Reversible piston to SOLO TO GREAT.
Cancelling piston to take in all stops (except Echo).
Reversible foot piston to Swell TREMULANT.
Reversible foot piston to Solo TREMULANT.
Lock for each adjustable piston.
Four balanced crescendo pedals to Choir, Swell, Solo and Echo organs.

Wind Pressures.

Pedal flue-work, 3½ inches to 6 inches; reeds, 6 inches and 20 inches.

Choir, 3½ inches.

Great flue-work, 3½ and 4½ inches; reeds, 12 inches.

Swell flue-work and Oboes, 5 inches; other reeds, 8 inches.

Solo flue-work and light orchestral reeds, 6 inches; Tubas, Orchestral Trumpet and French Horn, 20 inches.

Action, 12 inches.

The drawstop jambs are at an angle of 45 degrees to the keyboards. The stop handles are of solid ivory, the speaking stops being lettered in black and the couplers, etc. (indicated above by small capitals) in red. The couplers are grouped with the speaking stops of the departments they augment, The combination pistons are of solid ivory.

The mechanism is on the builders' latest electric system.

The best of the pipe-work from the old organ, especially that of historic interest, has been retained and carefully restored and revoiced.

The pitch is C = 522 vibrations at 60 degrees F.

The blowing is by "Discus" fans and electric motor, by Messrs. Watkins and Watson, Ltd., of London. There is a special apparatus for humidifying and purifying the wind before it passes into the organ.

ECHO or CELESTIAL ORGAN

(in a swell-box).

18 Stops, 2 TREMULANTS and 6 COUPLERS.

Pedal, 2 Stops, 2 COUPLERS.

				feet
1.	Double Salicional	(from No. 3)	Metal and Wood,	16
2.	Corno di Bassetto	(from No. 15)	Metal,	16

I. ECHO (first division) TO PEDAL.
II. ECHO (second division) TO PEDAL.

First Division, 7 Stops, TREMULANT AND 2 COUPLERS.

				feet
3.	Double Salicional		Metal and Wood,	16
4.	Viola da Gamba		Metal,	8
5.	Voix Célestes	ten C.	,,	8
6.	Hohl Flote		Wood,	8
7.	Dulcet		Metal,	4
8.	Dulciana Cornet	10, 12, 15, 17, 19, 22	,,	—
9.	Vox Humana		,,	8

III. TREMULANT.
IV. OCTAVE.
V. SUB OCTAVE.

Second Division, 9 Stops, TREMULANT AND 2 COUPLERS.

			feet
10.	Cor de Nuit	Metal and Wood,	8
11.	Unda Maris	,, ,,	8
12.	Flauto Traverso	Metal,	4
13.	Flageolet	,,	2
14.	Glockenspiel, 3 ranks	,,	—
15.	Corno di Bassetto	,,	16
16.	Harmonic Trumpet	,,	8
17.	Oboe	,,	8
18.	Gongs	,,	8

VI. TREMULANT.
VII. OCTAVE.
VIII. SUB OCTAVE.

Accessories.

Three adjustable combination pistons to the first division.
Three adjustable combination pistons to the second division.
Eight switches for keyboard control.
Balanced crescendo pedal.

Wind Pressures.

Flue-work and Vox Humana, 3 inches; other reeds, 5 inches.

Action wind, 8 inches.

Both divisions of the Echo organ will be playable on any of the four keyboards of the Main organ and will be controlled by the eight switches, one for each division to each keyboard.

The stops and couplers, etc., will be controlled by tablets placed above the Solo keyboard.

The blowing for the Echo organ will be by separate "Discus" fans and electric motor by Messrs. Watkins and Watson, Ltd.

The Organ in Westminster Cathedral

THE organ was built by Messrs. Henry Willis and Sons in 1922, and the complete scheme carried out in 1932.

There are two consoles, one attached to the "Grand Organ" in the West Gallery, the other detached and situated in the Apse at the East end, controlling the Grand Organ and the Apse Organ.

Grand Organ—West Console

4 Manuals, CC to C, 61 notes.

"Willis" Pedal Board, CCC to G, 32 notes.

Great Organ, 19 Stops.

				feet
1.	Double Open Diapason		Metal,	16
2.	Bourdon		Std. Wood and Metal,	16
3.	Open Diapason No. 1		Metal,	8
4.	Open Diapason No. 2		,,	8
5.	Open Diapason No. 3		,,	8
6.	Flute Harmonique		,,	8
7.	Quint		,,	$5\frac{1}{3}$
8.	Octave		,,	4
9.	Principal		,,	4
10.	Flute Couverte		Std. Metal,	4
11.	Tenth		Metal,	$3\frac{1}{5}$
12.	Octave Quint		,,	$2\frac{2}{3}$
13.	Twelfth		,,	$2\frac{2}{3}$
14.	Super Octave		,,	2
15.	Fifteenth		,,	2
16.	Grand Chorus	(15, 19, 22, 26, 29)	,,	5 rks.
17.	Double Trumpet	heavy	,,	16
18.	Trumpet	wind harm.	,,	8
19.	Clarion	trebles	,,	4

(Enclosed)

Swell Organ, 15 Stops and Tremulant.

				feet
20.	Violon		Metal,	16
21.	Geigen Diapason		,,	8
22.	Rohr Flute		Wood and Metal,	8
23.	Echo Viole		,, ,,	8
24.	Viole Céleste	(AA)	,, ,,	8
25.	Octave Geigen		Metal,	4
26.	Suabe Flute	(triangular)	Wood,	4
27.	Twelfth		Metal,	$2\frac{2}{3}$
28.	Fifteenth		,,	2
29.	Harmonics	(17, 19, 22)	,,	3 rks.
30.	Vox Humana		,,	8
31.	Oboe		,,	8
32.	Tremulant			—
33.	Waldhorn	heavy	,,	16
34.	Trompette	wind harm.	,,	8
35.	Clarion	trebles	,,	4

(Enclosed)

Choir Organ, 12 Stops and Tremulant.

				feet
36.	Contra Dulciana		Metal	16
37.	Open Diapason		,,	8
38.	Viola		,,	8
39.	Cor-de-Nuit		Std Wood and Metal,	8
40.	Cor-de-Nuit Céleste	(T.C.)	Std. Metal,	8
41.	Sylvestrina		Metal,	8
42.	Gemshorn		,,	4
43.	Nason Flute		Std. Wood,	4
44.	Nazard	(top 12 open, conical)	Std. Metal,	$2\frac{2}{3}$
45.	Octavin	(top 18 open, conical)	,, ,,	2
46.	Tierce	(top 24 open, conical)	,, ,,	$1\frac{3}{5}$
47.	Trumpet		Metal,	8
48.	Tremulant			—

(Enclosed)

Solo Organ, 14 Stops and Tremulant.

				feet
49.	Quintaten		Std. Metal,	16
50.	Violoncello		Metal,	8
51.	'Cello Céleste	(Bass from No. 50)	,,	8
52.	Tibia		Wood,	8
53.	Salicional		Metal,	8
54.	Unda Maris	(Bass from No. 53)	,,	8
55.	Concert Flute		,,	4
56.	Piccolo Harmonique		,,	2
57.	Cor Anglais		,,	16
58.	Corno-di-Bassetto		,,	8
59.	Orchestral Oboe		,,	8
60.	Tremulant			—
61.	French Horn	heavy wind harmonic	,,	8
62.	Orchestral Trumpet		,,	8
63.	Tuba Magna		,,	8

Pedal Organ, 18 Stops.

				feet
64.	Double Open Bass	(20 from No. 65)	Wood,	32
65.	Open Bass		,,	16
66.	Open Diapason		Metal,	16
67.	Contra Bass		,,	16
68.	Sub Bass		Wood,	16
69.	Violon	(from No. 20)	Metal,	16
70.	Dulciana	(from No. 36)	,,	16
71.	Octave	(20 from No. 65)	Wood,	8
72.	Principal	(20 from No. 66)	Metal,	8
73.	Flute	(20 from No. 68)	Wood,	8
74.	Super Octave	(20 from No. 72)	Metal,	4
75.	Seventeenth		,,	$3\frac{1}{5}$
76.	Nineteenth		,,	$2\frac{2}{3}$
77.	Twenty-second		,,	2
78.	Contra Trombone	(20 from No. 79)	,,	32
79.	Trombone	(heavy wind)	,,	16
80.	Octave Trombone	(20 from No. 79)	,,	8
81.	Bombarde	(very heavy wind)	,,	16

Couplers.

1. Solo to Pedal.
2. Swell to Pedal.
3. Great to Pedal.
4. Choir to Pedal.
5. Swell to Great
6. Choir to Great.
7. Solo to Great.
8. Swell Octave.
9. Swell Sub Octave.
10. Swell Unison Off.
11. Choir Octave.
12. Choir Sub Octave.
13. Choir Unison Off.
14. Swell to Choir.
15. Solo to Choir.
16. Solo Octave.
17. Solo Sub Octave.
18. Solo Unison Off.
19. Swell Reeds to Solo.
20. Great Reeds to Solo.
21. Great and Pedal Combinations Coupled.

Accessories.

6 Pistons to Great Organ.
6 Pistons to Swell Organ.
6 Pistons to Choir Organ.
6 Pistons to Solo Organ.
6 Pedal Pistons to Pedal Organ.
1 Reversible to Great Reeds to Solo.
I Reversible to Swell Reeds to Solo.
*1 Reversible Piston to Great to Pedal.
*1 Reversible Piston to Swell to Pedal.
*1 Reversible Piston to Choir to Pedal.
*1 Reversible Piston to Solo to Pedal.
1 Reversible Piston to Swell to Great.
1 Reversible Piston to Solo to Great.
1 Reversible Piston to Choir to Great.
1 Reversible Piston to Swell to Choir.
1 Reversible Piston to Solo to Choir.

* Duplicated by toe-pistons.

Balanced Swell Pedals to Swell, Choir and Solo Organs.
Tubular-pneumatic action.
Electric Blowers.

Apse Console.

THE APSE CONSOLE CONTROLS GRAND AND APSE ORGANS.

The Grand Great, Swell, Choir, Solo and Pedal Stops are duplicated on Apse console as above but are controlled by the following couplers and accessories:—

Couplers.

1. Swell to Great.
2. Swell to Great Octave.
3. Swell to Great Sub Octave.
4. Choir to Great.
5. Solo to Great.
6. Solo to Great Octave.
7. Solo to Great Sub Octave.
8. Swell Octave.
9. Swell Sub Octave.
10. Swell Unison Off.
11. Solo to Swell.
12. Choir Octave.
13. Choir Sub Octave.
14. Choir Unison Off.
15. Swell to Choir
16. Swell to Choir Octave.
17. Swell to Choir Sub Octave.
18. Solo to Choir.
19. Solo to Choir Octave.
20 Solo to Choir Sub Octave.
21. Solo Octave.
22. Solo Sub Octave.
23. Solo Unison Off.
24. Swell to Pedal.
25. Swell to Pedal 4 ft.
26. Choir to Pedal.
27. Solo to Pedal.
28. Solo to Pedal 4 ft.
29. Great to Pedal.
30. Great and Pedal Combinations Coupled.

Accessories.

7 Pistons to Great Organ.
*7 Pistons to Swell Organ.
5 Pistons to Choir Organ.
7 Pistons to Solo Organ.
7 Toe Pistons to Pedal Organ.
4 General Pistons.
1 General Cancel Piston.

* Duplicated by toe-pistons.

1 Locking Piston for adjusting all combinations while seated at the console.

*1 Reversible Piston to Great to Pedal.
1 Reversible Piston to Swell to Pedal.
1 Reversible Piston to Choir to Pedal.
1 Reversible Piston to Solo to Pedal.
1 Reversible Piston to Swell to Great.
1 Reversible Piston to Solo to Great.
1 Reversible Piston to Choir to Great.
1 Reversible Piston to Swell to Choir.
1 Reversible Piston to Solo to Choir.
1 Reversible Piston to Solo to Swell.
1 Reversible Piston to Great and Pedal Combinations Coupled.

1 Switch: Grand Organ / Both / Apse Organ.
1 Full Organ toe-piston with indicator.
Balanced Swell Pedal to Grand and Apse Swell Organs.
Balanced Swell Pedal to Grand Solo Organ.
Balanced Swell Pedal to Grand Choir Organ.
Balanced Register Crescendo Pedal with indicator.
Electro-pneumatic Action.

Apse Section.

Two Manuals, CC to C, 61 notes, and "Willis" Pedal Board,
CC to G, 32 notes.

Great Organ, 7 Stops.

			feet
82.	Open Diapason	Metal,	8
83.	Hohl Flute	,,	8
84.	Dulciana	,,	8
85.	Octave	,,	4
86.	Harmonic Flute	,,	4
87.	Flautina	,,	2
88.	Trumpet	,,	8

I. Swell to Great Unison.
II. Swell to Great Octave.
III. Swell to Great Sub Octave.

(Enclosed)

Swell Organ, 5 Stops.

			feet
89.	Salicional	Metal,	8
90.	Unda Maris (AA)	,,	8
91.	Lieblich Gedackt	Std. Wood and Metal,	8
92.	Oboe	Metal,	8
93.	Horn	,,	8

IV. Swell Octave.
V. Swell Sub Octave.
VI. Swell Unison Off.

Pedal Organ, 3 Stops.

			feet
94.	Sub Bass (3 notes to AAA, rest from 95)		32
95.	Bourdon	Std. Wood	16
96.	Flute (20 from 95)		8

VII. Great to Pedal.
VIII. Swell to Pedal.
IX. Swell Octave to Pedal.
X. Great and Pedal Combinations Coupled.

Accessories.

3 Pistons to Great Organ.
*3 Pistons to Swell Organ.
3 Toe Pistons to Pedal Organ.
*1 Reversible Piston to Great to Pedal.
1 Reversible Piston to Swell to Pedal.
1 Reversible Piston to Swell to Great.
1 Reversible Piston to Great and Pedal Combinations Coupled.

* Duplicated by toe-pistons.

Wind Pressures.

Great Organ—	
Light wind	4¼ ins.
Heavy wind (reeds and Open 1)	12 ins.
Swell Organ—	
Light wind	5½ ins.
Heavy wind (chorus reeds)	15 ins.
Choir Organ—	
All	5¾ ins.
Solo Organ—	
Light wind	7 ins.
Heavy wind (Fr. Horn, Trumpet and Tuba)	30 ins.
Pedal—	
Various, but Trombone	20 ins.
Various, but Con. Trombone (12 notes)	30 ins.
Bombarde	30 ins.
Apse Organ—	
Great	4¾ ins.
Swell	4 ins.

The Organ in Wolverhampton Civic Hall

THE organ was built in 1938 by the John Compton Organ Company, and is a very fair representation of the type of instrument associated with the name of John Compton. The specification was drawn up by Mr. Compton, with the assistance of Mr. J. Gilbert Mills, of Birmingham. The organ chamber is above the roof of the hall and is only 12 ft. high by 14 ft. deep; it is divided into two swell boxes. In order to show as clearly as possible which of the ranks are "straight" and which "extended" or "duplexed," the stops have been set out in parallel columns. There are 40 independent stops and 50 ranks of pipes. The Great and Swell divisions are complete independently of any manual extensions. There was no room for more independent pipe-work on the pedal.

There are
8 double-touch thumb pistons to the Choir and Pedal organs.
6 ,, ,, ,, ,, Great ,, ,,
6 ,, ,, ,, ,, Swell ,, ,,
6 ,, ,, ,, ,, Solo ,, ,,
4 reverser thumb pistons for the pedal couplers.
6 toe pistons to the Pedal organ.
6 ,, ,, Great ,,
6 ,, ,, Swell ,,
2 ,, ,, Sustainers.
6 general pistons operating stops of all departments simultaneously.
1 general cancel piston, taking off all stops.

All the pistons are adjustable by the organist.

There is also an electronic section, playable only from the solo manual, producing, *inter alia*, effects of solo flutes, solo reeds, chimes and reverberation.

In Chamber I	Ft.	Pipes	Pedal	Choir	Great
1. Contra Bass	16	56	16, 8, 4		
2. Sub Bass	32	68	32, 16, 8, 4		
3. Bombarde	16	56	16, 8, 4		
4. Contra Salicional	16	109	16, 8	16, 8, 4, 2⅔, 2, 1⅓, 1	
5. Gemshorn	8	61		8	
6. Vox Angelica	4	49		8 (tenor C)	
7. Lieblich Gedeckt	16	97	16	16, 8, 4, 2	
8. Claribel Flute	8	61		8	
9. Flauto Traverso	4	61		4	
10. Nasard	2⅔	61		2⅔	
11. Tierce	1⅗	61		1⅗	
12. Double Open Diapason	16	97	16, 10⅔, 5⅓	8	16, 8, 4, 2
13. First Diapason	8	61			8
14. Second Diapason	8	61			8
15. Stopped Diapason	8	61			8
16. Octave	4	61			4
17. Twelfth	2⅔	61			2⅔
18. Super Octave	2	61			2
19. Fourniture IV ranks	1⅓	244			IV
20. Harmonics V ranks	6⅖	364	V (32 ft.) V (16 ft.)		V (8 ft.)
21. Contra Posaüne	16	85	16, 8	8	16, 4
22. Tromba	8	61			8
23. Horn	8	61			8

In Chamber II				Swell	Solo
24. Contra Viola	16	85	16	16, 8, 4	
25. Geigen	8	61		8	
26. Voix Célestes	8	61		8	
27. Rohrflöte	8	61		8	
28. Geigen Octave	4	61		4	
29. Fifteenth	2	61		2	
30. Mixture IV ranks	1⅓	244		IV	
31. Double Trumpet	16	85	16	16, 4	8
32. Trumpet	8	61		8	
33. Hautboy	8	61		8	
34. Violoncello	8	61			8
35. Viole Céleste	8	61			8
36. Harmonic Flute	8	61			8
37. Harmonic Flute	4	61			4
38. Clarinet	8	61			8
39. Orchestral Oboe	8	61			8
40. Tuba	8	73			8, 4

Couplers, etc.

Choir to Pedal.
Great to Pedal.
Swell to Pedal.
Solo to Pedal.
Solo Octave to Pedal.

Great to Choir.
Swell to Choir.
Solo to Choir.
Choir Sustainer.
Choir Tremulant.

Swell to Great.
Solo to Great.

Swell Suboctave.
Swell Octave.
Solo to Swell.
Swell Tremulant.

Solo Suboctave.
Solo Octave.
Solo Sustainer.
Solo Tremulant.

Appendix I.

THE following description of pipework as used by the Aeolian-Skinner Organ Company, Boston, Mass., U.S.A., will be of great interest to all organ lovers.

Koppelflöte. Also used as a Nazard 2⅔ in.

2 ft. C scale, 2½ in., mouth ¼. Slightly arched, cut ¼ to top of arch. ¾ in. opening at top of cone. Cone ¼ length of pipe. increasing as the compass ascends. 1 ft. C has a scale of 1-7/16 in. 6 in. C scale 13/16 in. The cut-up is lowered in treble. No flattening of upper lip. The canister top supporting the cone has the lower edge cut in a semi-spiral and a tit is soldered on the pipe, so the canister cannot slip. There is no packing, the top being fitted carefully to the pipe. The trebles are built up in power. The tone is very beautiful with a kind of transparent body. It is an excellent blender. Material preferably about 80% tin, but spotted metal will do, but the tone suffers slightly.

Koppel Gedackt and **Spillflöte** are modifications of the above. The former has a closed top and the latter has the cone portion half the length of the pipe body.

Rohrflöte. 2 ft. C, scale 2-1/16 in. (cut up 2/7) (mouth ¼), slightly arched; no flattening of upper lip. Chimney ½ in. diameter. Felt packing for canister. Spotted metal.

Bourdon. Similar to Rohrflöte, but with solid cap.

Nachthorn. Open metal 30% tin. Scales, 4 ft. C = 3-7/16 in., 2 ft. C = 2¼ in., 1 ft. C = 1-7/16 in. ⅙th mouth cut up ¼. Full smooth flute tone.

Blockflöte. 2 ft. C = 2-3/8 in. at mouth, ⅔rds diameter at top; mouth ¼ cut up ¼, slightly arched. Fine nicking; tin preferred. 1 ft. C = 1¾ in. at mouth; 6 in. C = 1 in. at mouth.

This type of stop is also used often for special types of mutations, such as 2⅔ ft., 1-3/5 ft., and 1⅓ ft. The Tierce has ⅙th mouth. The voicing is quite bold.

8 ft. Gedackt, 4 ft. Nachthorn, 2⅔ ft. Nazard, 2 ft. Blockflöte and 1-3/5 ft. Tierce create a Cornet tone of smooth but powerful tone.

Sifflöte 1 ft. Low C 1½ in.; ⅙ mouth, ¼ cut up; tin.

REEDS.

Cromorne or Krummhorn. 4 ft. C of cylindrical resonator ¾ in., 2 ft. C=5/8 in., 1 ft. C=½ in. There is no inverted cone at the base of the resonator; not only does it go down to the block at the full diameter, but the latter is bored out so that the tube continues to the end of the shallot. The shallot is small, and tapered with a wide opening. Tongues are thin. Pressure 2½ in. to 5 in. The tone is powerful and similar to the Clarinet, with the fundamental greatly reduced in power and the characteristic harmonics greatly increased. It is a wonderful solo stop and is equally good as a chorus reed. One trick to make these pipes stable consists of giving the resonators plenty of "belly." In the treble they gradually flare at the top to keep up the power.

Rohr Schalmei. See Plate VI. Scale at 4 ft. C, 2¾ in.; body of pipe 8¼ in. long. Resonator, 2 ft. C, scale 1 in. Rohr, 3/8 in. brass. Tone more pure than Cromorne. Very lovely in solo or chorus use.

Rankett. See Plate VI. Scale at 4 ft. C, 2¾ in.; body of pipe 8¼ in. long. Boot 2 ft. long. Notice that the cylindrical body extends down to the block and the tone issues through holes in the lower part of the body partially covered by a slide. The top of the resonator is closed. Internally there is a second portion of the resonator in the form of an inverted cone like a small-scaled Trumpet. This latter is open at the top and terminates about ½ in. from the cap of the main resonator. Note the unusual length of the boot.

Chorus Reeds. Those preferred are refined versions of Cavaillé-Coll even to the Pedal 16 ft. and 32 ft. reeds in our later organs. No loading of tongues is employed. The speech of both 16 ft. and 32 ft. is much faster than the short loaded tongues usually used. No starters are necessary on the 32 ft. The objectionable "cough" in the speech of the low notes is entirely eliminated, and a much more even result is obtained. CCC of a Pedal 16 ft. has a vibrating length of 5-3/8 in., pressure 5 in. The tongues are draw filed so as to be thicker at the free end. This makes for an absolutely steady tone.

MIXTURES.

Typical Great Fourniture IV and Cymbel III.

Fourniture (IV) (Large scale)

15 - 19 - 22 - 26 18 Notes
12 - 15 - 19 - 22 12 ,,
8 - 12 - 15 - 19 12 ,,
1 - 8 - 12 - 15 19 ,,

CYMBEL (III) (Medium scale)

22 - 26 - 29 18 Notes
19 - 22 - 26 12 ,,
15 - 19 - 22 12 ,,
12 - 15 - 19 12 ,,
8 - 12 - 15 7 ,,

Great Fourniture (III to V Rks.) Worcester Art Museum.

15 - 19 - 22	12 notes
12 - 15 - 19 - 22	18 ,,
8 - 12 - 15 - 19	6 ,,
1 - 8 - 12 - 15	12 ,,
1 - 5 - 8 - 12 - 15	13 ,,

70% Tin.

Recit Cymbel (IV) (Medium scale).

26 - 29 - 33 - 36	18 Notes
22 - 26 - 29 - 33	6 ,,
19 - 22 - 26 - 29	6 ,,
15 - 19 - 22 - 26	6 ,,
12 - 15 - 19 - 22	6 ,,
8 - 12 - 15 - 19	6 ,,
1 - 8 - 12 - 15	13 ,,

70% Tin.

Typical Zimbel (III) (Small scale).

29 - 33 - 36	12 Notes
26 - 29 - 33	6 ,,
22 - 26 - 29	6 ,,
19 - 22 - 26	6 ,,
15 - 19 - 22	6 ,,
12 - 15 - 19	6 ,,
8 - 12 - 15	6 ,,
5 - 8 - 12	6 ,,
1 - 5 - 8	7 ,,

Great or Swell **Plein Jeu (VI)** (Various scales).

12 - 15 - 19 - 22 - 26 - 29	18 Notes
8 - 12 - 15 - 19 - 22 - 26	12 ,,
1 - 8 - 12 - 15 - 19 - 22	12 ,,
1 - 8 - 12 - 15 - 15 - 19	12 ,,
1 - 8 - 8 - 12 - 15 - 15	7 ,,

Naturally where there are two 15ths, for example, they are scaled and voiced differently.

Appendix II.

The following is a description of the electric stop-key mechanism and adjustable piston control as designed and made by Mr. C. Horace Clarke for his chamber organ at "Dorincourt," Snaresbrook (Essex).

All directions and positions are considered as seen from the front of the key desk, i.e., the left of the figure.

The key contacts are of the standard form of 8 hard silver wires, bridged on depressing a key. If a live bridge is used with a flexible conductor to it, all

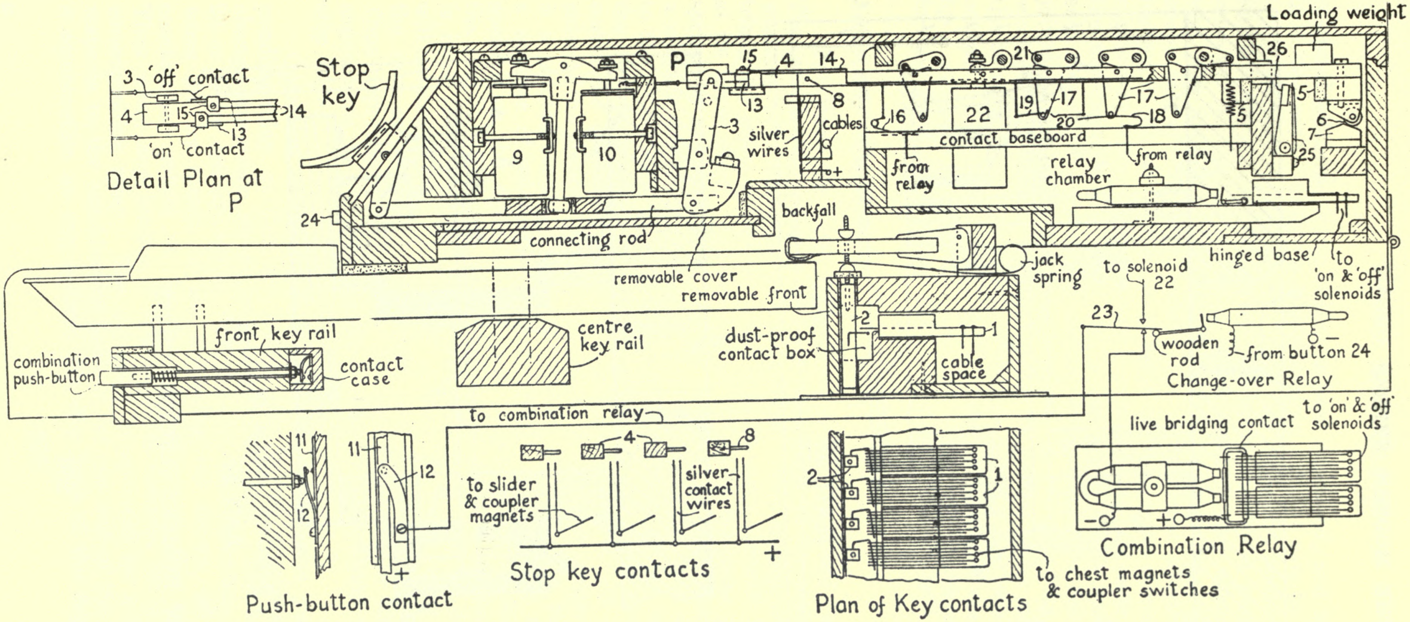
8 wires are available for cables to chest magnets and couplers. In the present case one of the wires in each group is live, a bus-bar being run along and connected to each. Each silver wire is rivetted and soldered to a saw-cut in the head of an ordinary brass pin, the point of which is cut off after insertion in the contact block, shown at 1. All the contact blocks are glued on to paper felt in a dust-proof box at the rear end of the keys. The bridging contact is a bent silver wire, 20 S.W.G., held in a wooden jack 2 which is lifted by a backfall when the key is depressed. The forward end of the backfall merely rests on the key tail, and the whole box can be lifted out without disturbing any connections or adjustments. The front is removable to give access to contacts, and the back and part of base to give access to cable connections soldered to the aforesaid pins. The bridging contacts are sloped as shown on detail plan so as to clear one another if there should be slight twisting of the jacks.

The stop keys are arranged in a single row above the top clavier and are quadrant in form, pivoted at the back, with the name and pitch engraved on the upper part, facing the player. Stop keys can be tilted "on" or "off" by the forwardly projecting lower part in known manner, and this shows easily which keys are "on." Alternatively, they can be put "off" by pushing the upper part.

When the stop key is tilted, the connecting rod operates the rocker 3 which pulls forward the switch rod 4. The rocker 3 is provided with an adjustable weight which counterbalances the stop key. The switch rod passes right to the back of the case where the felt buffers 5 limit its movement. The tail of the rod carries a roller 6 which rides up either side of an arris rail 7, and the rod is loaded with a weight, so that it is bound to pass either to the "on" (forward) or "off" (rearward) position with a snap action. This arrangement is preferable to a snap-over spring, as the full force is available for moving the mechanism all the way from the central point. Forward movement of the switch rod causes the silver pin 8 to bridge a pair of silver wires, one of which is alive to the positive main and the other connected to that magnet which the particular stop key is to operate, either a slider or a coupler. The detail diagram of stop key contacts makes the arrangement plain. The rest of the mechanism is for the combinational operation of the stop keys.

Each stop key can be operated electrically by either the "on" solenoid 9 or "off" solenoid 10. These work through the T-rocker shown to push the connecting rod backwards or forwards respectively. The solenoids are energised when the combination push button in front key rail is depressed. The button is a polished boxwood knob held forward by a spring and extended by a smaller (metal) rod to the rear of the key rail where it is retained by a nut. Inside the dust-proof contact case fixed to the rear of the key rail is a live bus-bar 11, and for each button there is a contact spring 12. Silver tips are rivetted into both 11 and 12. The case with its contacts and cables can be removed without disturbing the button adjustments. Each contact spring 12 is connected to a combination relay which carries a number of contacts connected as required to the "on" or "off" solenoids according to the combination. The standard key contact blocks are used for the relay, one or more as required, and are bridged by a live contact.

The "on" and "off" solenoids are supplied via the switch rods, so that the movement switches off the current after the operation. This prevents:—slamming the mechanism hard over, waste of current in a large number of

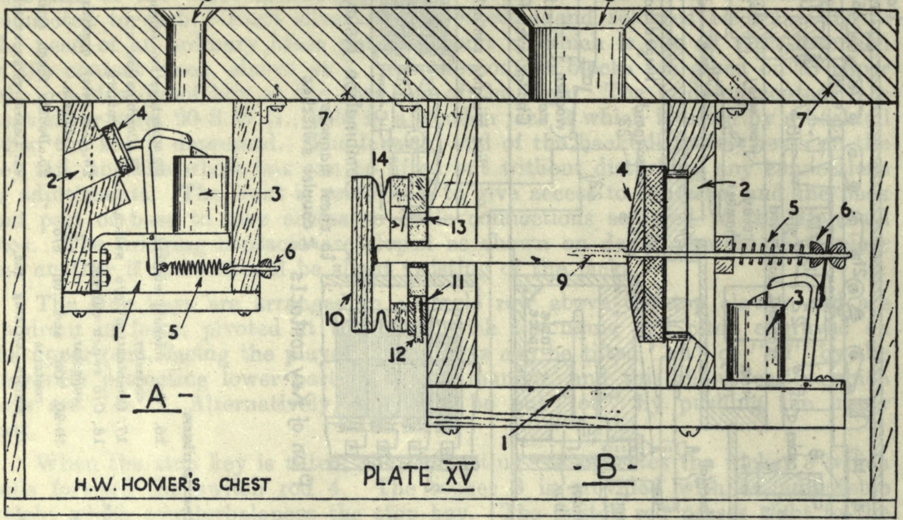

Loading weight
Stop key
3 'off' contact
4
15
13
>14
'on' contact
Detail Plan at P
P
15
4
14
8
13
3
silver wires
cables
+
9
10
24
connecting rod
removable cover
removable front
backfall
16
from relay
22
contact baseboard
21
19
17
20
17
18
from relay
relay chamber
26
5
5
6
7
25
jack spring
hinged base
to 'on & 'off' solenoids
to solenoid 22
23
wooden rod
from button 24
Change-over Relay
front key rail
combination push-button
contact case
centre key rail
dust-proof contact box
2
1
cable space
to combination relay
11
12
11
12
+
Push-button contact
to slider & coupler magnets
4
8
silver contact wires
+
Stop key contacts
2
1
to chest magnets & coupler switches
Plan of Key contacts
live bridging contact
to 'on' & 'off' solenoids
−
+
Combination Relay

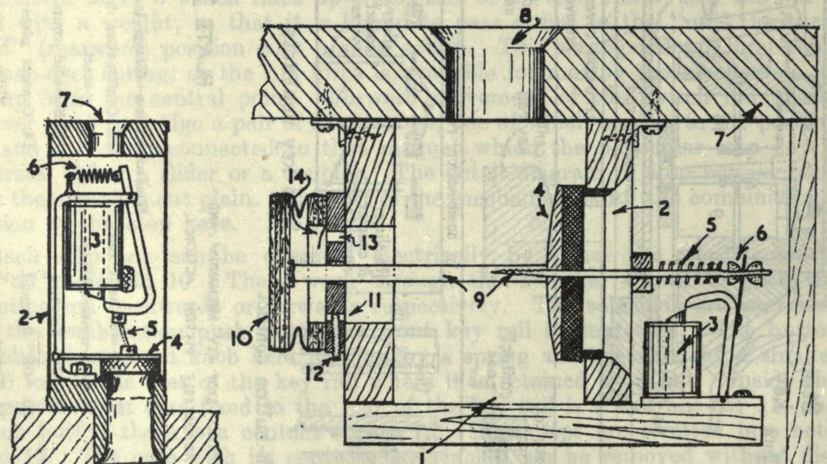
ELECTRIC STOP KEY MECHANISM AND ADJUSTABLE PISTON ACTION

PLATE XIV

References—Stop-key Mechanism

1. Key contact blocks.
2. Contact bridge jacks.
3. Stop-key counter-balance rocker.
4. Switch rod.
5. Switch rod stop buffers.
6. Snap-over roller.
7. Snap-over arris rail.
8. Stop contact bridge.
9. "On" Solenoid
10. "Off" Solenoid.
11. Combination button bus-bar.
12. Combination button contact.
13. Solenoid contact plate.
14. Contact plate supply wires.
15. Contact plate clamps.
16. "On" solenoid current collector.
17. Combination c/o switch.
18. C/o switch current collector.
19-20. "On" and "off" c/o contacts
21. Switch striking rod.
22. Combination solenoid.
23. Combination c/o contacts.
24. C/o relay operating button.
25. Double touch spring.
26. Cancel relay switch.


8
8
4
7
7
2
3
14
2
13
5
6.
6
9
11
10
1
5
3
12
-A-
1
H.W. HOMER'S CHEST
PLATE XV
-B-


8
7
7
6
14
4
2
13
3
5
6
9
11
2
5
4
10
3
12
1
1
A
IMPROVED VERSION OF
PLATE XV
B

H. W. HOMER'S ELECTRIC CHEST

powerful solenoids if the button is held depressed, and burning of relay contacts in a like case. Only the relay magnet current can be held on. The solenoid terminals consist of the "on" and "off" collector contacts on either side of the forward end of the switch rod shown in the detail plan at P. Each of these collector contacts bears on a silver plate 13 and when the rod moves, either way, the respective plate passes out of engagement with the contact wire and opens the circuit. The plates can be adjusted lengthways to determine the instant at which current is switched off to prevent rebound. It is usually about mid-stroke, after which the momentum and the snap-over loading weight complete the movement. Current is led to the plates 13 by means of wires 14, one on each side of the switch rod, carried to the top of the rod at its forward end, and joined to the plate clamping washers 15. Current is conveyed to the "on" conductor 14 by the collector spring 16, which slides in a silver-lined groove in the contact baseboard. The silver foil lining the groove is connected to a relay contact. The "off" conductor 14 on the other side of the rod is similarly supplied by a collector (not shown) near the other end of the rod. The relay contacts for any fixed combination are connected to these "on" and "off" collectors.

Adjustable Combinations.

For these the relay connections to the "on" and "off" wires 14 are varied. The switch rod carries a change-over switch 17 for each adjustable combination working over the stop key concerned. The change-over switch is a pivoted triangular plate (which does not have to carry current) having a silver cross pin at its lower point. On one side of the plate the cross pin engages the collector spring 18 supplied from a relay contact; on the other side it engages either a contact clip 19 connected to the "on" wire 14, or a contact clip 20 connected to the "off" wire 14, according to the position of the switch plate. To balance the upward pressure of all the springs 18 and avoid tilting the switch rod sideways, the collectors for all the switchplates of a rod are located on alternate sides of the plates. Across all the switch rods over which the combination operates is a pivoted rocking frame, the rod 21 of which can be depressed when one of a number of solenoids 22 is energised. This moves the c/o switch into one position or the other according to which corner of the switch plate is under the rod 21. This will be settled by the position of the switch rod. If the rod is back (stop key "off") the forward corner will be depressed and the switch will be pushed over to the "off" contact 20; if the rod is forward (stop key "on") the rear corner will be depressed and the switch pushed to "on" contact 19. Thus depression of a rod 21, by operating solenoid 22, automatically sets the connections to the corresponding relay in accordance with the position of the stop keys.

Operation of the solenoid 22 is from the same push-button as the corresponding relay, so that any button sets its own combination. This is done by a change-over relay, shown only diagrammatically. This has as many contact wires 23 as there are adjustable combinations, and operation of the relay lifts all the wires 23, by means of the insulating rod shown, off the connections to the combination relays on to the connections to the combination solenoids 22. Thus when any button is depressed its solenoid 22 is operated instead of the corresponding relay. The c/o relay is operated by a button 24, similar in all respects to the combination buttons, at one end of the stop key frame. To set a combination on any button, the stop keys of the department over which the combinations work are put ''on'' or ''off'' as desired for the combination, button 24 held in, and the button on which the combination is to be set is momentarily depressed. This finishes the operation. Thereafter, that button will always put the stop keys in that position, and the combination is visible. It is unaffected by any other movement of the stop keys individually.

The Double-Touch Cancel.

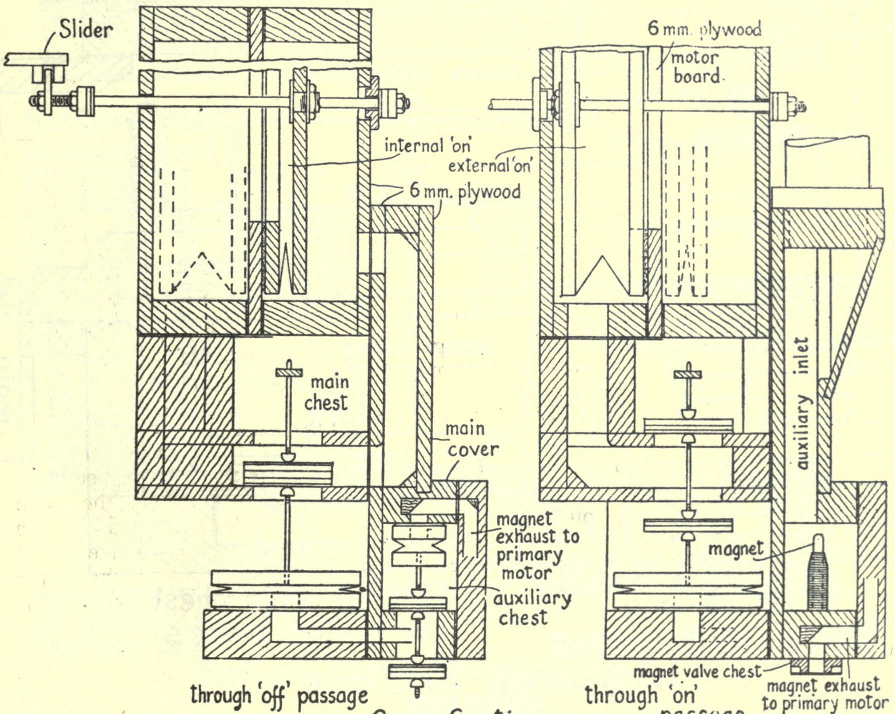
Each stop can be left as the only one ''on'' by an extra firm pressure on the stop key, which cancels all the other stops in the department. The ''on'' buffer stop 5 at the rear of the switch rod comes up against a stiff flat spring 25, one for each rod, which normally does not yield, but will do so if the stop key is pressed down harder. When any spring 25 is moved forward, a light pivoted frame 26, crossing all the switch rods of a department, is tilted and makes an electric contact. This is not shown, but is easily understood as being in the same manner as done by the slider and coupler contact pins 8 on the switch rods. The contact so made operates the cancel relay, whose contacts are all connected to the fixed current collectors of the ''off'' wires 14. This cancels all the stops of the department including any couplers to other departments (but does not affect other departments) and **including the stop whose key is being manipulated.** It cannot, however, put this off as the key is held; in any case if the pull overcomes the hand pressure it can put it off no farther than the normal ''on'' position, where the cancel relay would be switched off. In this manner, only one cancel relay per department, with a fixed set of connections, is required.

Appendix III.

Drawstop Slider Machines in Mr. C. H. Clarke's Organ

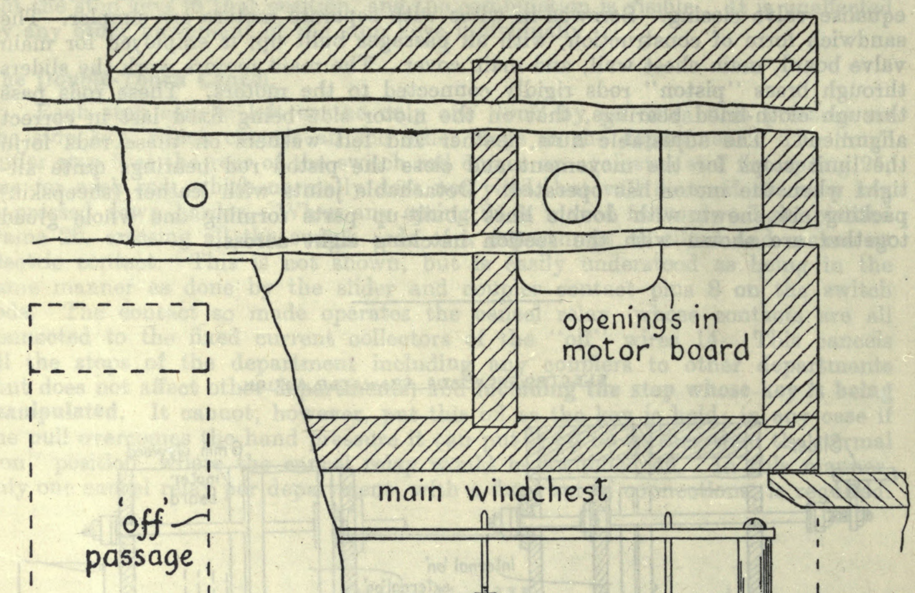
To enable large enough motors for low pressure (3 in.) to be got in the width of soundboard, they are arranged in two rows overlapping, the motors being mounted on opposite sides alternately of a plywood board which is sandwiched between the motor boxes. Square opening motors are used, made double-acting by closure in boxes. Wind to the box and motor exhausted moves slider one way; wind to inside of motor and box exhausted moves slider the other way. With all sliders moving ''on'' in the same direction, motors in the two rows work in opposite manners. The spaces between the motor boxes in each row form the wind passages to the motors in the other row. This is clearly seen in sectional plan of motor boxes. The valves are arranged in a single row along the main wind chest, the ''on'' and ''off'' passages passing alternately to one side or the other of the valve board, which forms the base of main chest. All the ''on'' passages pass through wall of chest, all the ''off'' passages through the cover of main chest. One main chest runs right across the sets of motors for two soundboards, the main inlet being in the bridge trunk between them. The main cover also carries within it the auxiliary chest, with magnets and primary motors and valves, and the auxiliary chest wind inlet. To give space for the latter between two ''off'' passages, the valve arrangements with corresponding magnets and primary motors for the end slider motor are changed over in position as shown on plan of main chest giving two ''on'' passages together. The sectional plan of motor boxes, projected from this, clearly shows the arrangement. The magnet exhausts for the primary motors pass slantwise through the auxiliary chest cover. One secondary motor, in place of two, could be used to work both valves, but that would mean jointed connections between valve stems and motor to equalise valve closing. Screwed-in wires with separate motors are simpler. The sandwich form of construction, with all passages built up, is employed for main valve board, main chest wall, and main cover. The main motors work the sliders through brass "piston" rods rigidly connected to the motors. These rods pass through cloth-lined bearings, that on the motor side being fixed last in correct alignment. The adjustable nuts, leather and felt washers on these rods form the limit stops for the movement and close the piston rod bearings quite air-tight when the motor has operated. Detachable joints with leather (sheepskin) packing are shown with double lines; built-up parts forming one whole glued together are shown with the section hatching right across.

ELECTRO-PNEUMATIC DRAWSTOP ACTION.


Slider
internal 'on'
external 'on'
6 mm. plywood
6 mm. plywood
motor board
main chest
main cover
magnet exhaust to primary motor
auxiliary chest
auxiliary inlet
magnet
magnet valve chest
magnet exhaust to primary motor
through 'off' passage
through 'on' passage

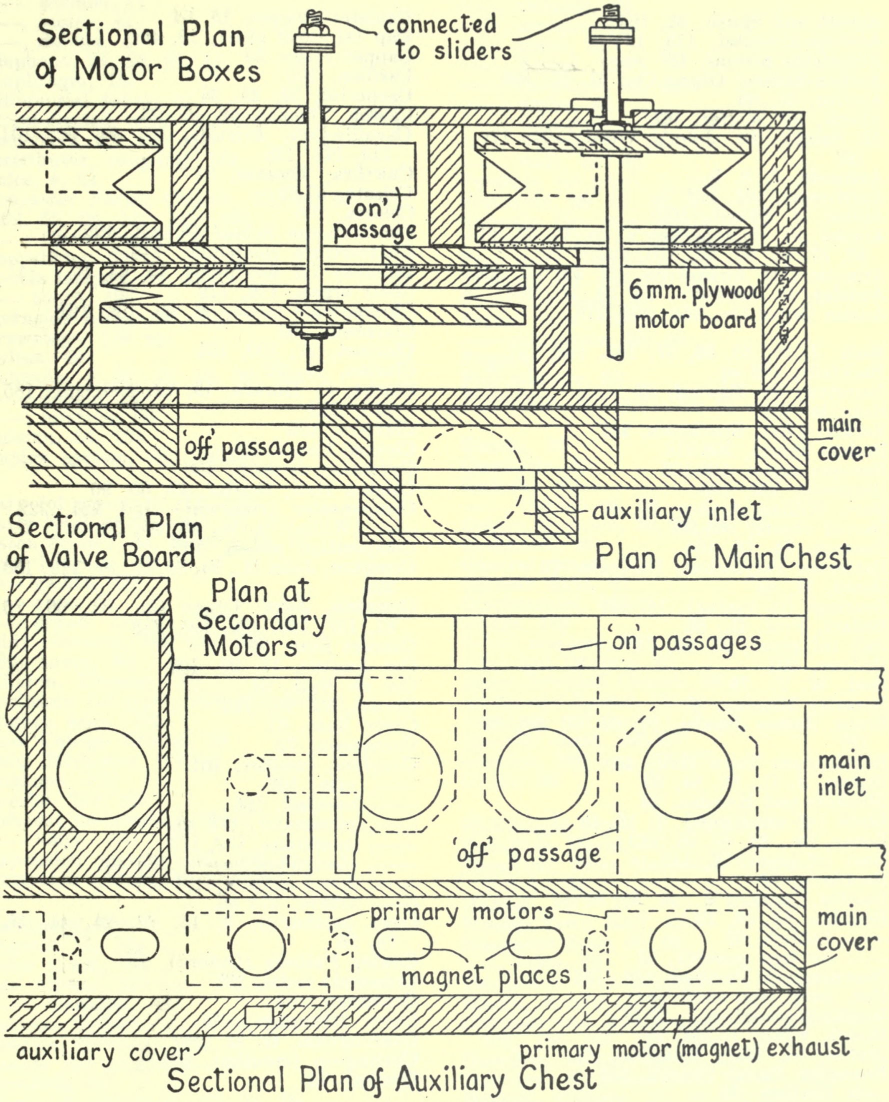
Cross Sections

PLATE XVI


openings in
motor board
main windchest
'off'
passage
main inlet
'off'
valve
'on'
valve
through main chest
& motor boxes
through auxiliary chest

Longitudinal Sections

PLATE XVII


Sectional Plan
of Motor Boxes
connected
to sliders
'on'
passage
6 mm. plywood
motor board
'off' passage
main
cover
auxiliary inlet
Sectional Plan
of Valve Board
Plan of Main Chest
Plan at
Secondary
Motors
'on' passages
main
inlet
'off' passage
primary motors
main
cover
magnet places
auxiliary cover
primary motor (magnet) exhaust
Sectional Plan of Auxiliary Chest

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